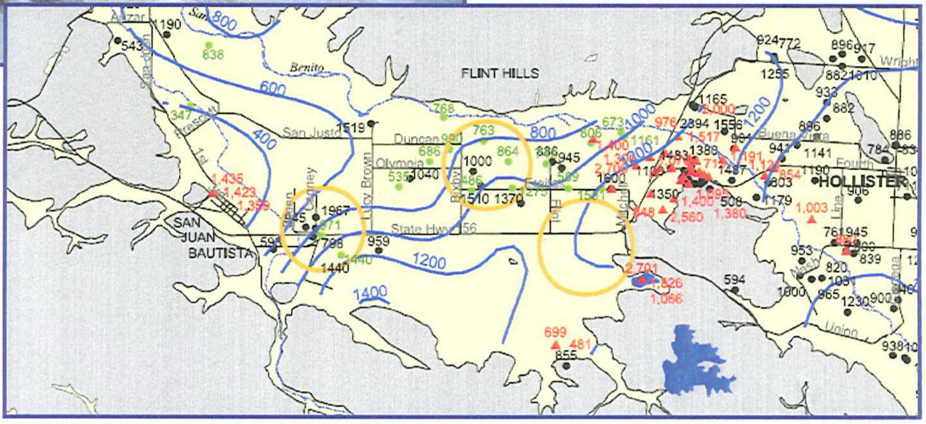
Pajaro River Watershed Groundwater Desalination Feasibility Study – Volume I: Report

San Benito County Water District
Santa Clara Valley Water District
Department of Water Resources Agreement #4600004126



September 27, 2007

RMC
Water and Environment

2290 N. First Street, Suite 212
San Jose, CA 95131
P: 408.240.8160 F: 408.240.8161

TD
478.5
P34.P3
2007
v.1
c.1
LIBRARY

TD478.5P34P32007v.1c.1

SAN BENITO COUNTY WATER DISTRICT
ESTABLISHED
NOV. 3, 1953
HOLLISTER, CA

Santa Clara Valley Water District

Pajaro River Watershed Groundwater Desalination Feasibility Study Report

MATTHEW PHILIP VAN HORNE
C70429
EXP. 09/30/08
CIVIL

9/27/2007

Prepared by:

RMC
Water and Environment

In Association with:

California Department of Water Resources
Gus Yates, RG CHG
HDR, Inc.
Lawrence Livermore National Laboratory
Water Quality and Treatment Solutions

SANTA CLARA VALLEY WATER DISTRICT
LIBRARY
5750 ALMADEN EXPRESSWAY
SAN JOSE, CALIFORNIA 95118

September 2007

Table of Contents

Executive Summary i
ES-1 Project Setting i
ES-2 Project Goals and Outcomes ii
ES-3 Project Recommendations iv
ES-4 Recommended Project Costs v
ES-5 Recommended Project Benefits vii
ES-6 Project Implementation ii

Chapter 1 Project Setting 1-1
1.1 Project Background 1-1
1.1.1 Project Location 1-1
1.1.2 Project History 1-4
1.2 Goals and Objectives 1-6
1.2.1 Feasibility Study Goals 1-6
1.2.2 Potential Implementation Projects 1-6
1.3 Concurrent Projects 1-7
1.4 Water Supply Summary 1-11
1.4.1 Existing Supplies 1-11
1.4.2 Projected Future Water Supply Needs 1-13
1.5 Existing Water Distribution Systems 1-14
1.6 Existing Wastewater Collection and Treatment Systems 1-15
1.7 Water Supply Impacts on Recycled Water Use 1-15
Chapter 2 Source Water Evaluation 2-1
2.1 Groundwater Basin Characteristics 2-1
2.2 CDPH Source Water Assessment Requirements 2-4
2.2.1 California Drinking Water Source Assessment and Protection Program 2-4
2.2.2 Characterization of the Water Source 2-6
2.3 Wellfield Siting Criteria 2-7
2.4 Initial Screening of Potential Wellfield Locations 2-8
2.4.1 Well Specific Capacity 2-9
2.4.2 Basin Hydraulic Conductivity 2-11
2.4.3 Nearby RWQCB Regulated Sites 2-12
2.4.4 Proximity to Existing Wells 2-14
2.5 Wellfield Design 2-15
2.5.1 Annual Extraction Volume 2-15
2.5.2 Well Spacing 2-15
2.6 Preliminary Groundwater Modeling 2-17
2.6.1 Simulation Parameters 2-17
2.6.2 Existing Conditions – Run 46 2-18
2.6.3 Water Level Impacts: Hydrographs 2-23
2.6.4 Water Level Impacts: Contours 2-28
2.6.5 San Juan Valley Groundwater TDS Changes 2-33
2.6.6 San Juan Valley Groundwater Budgets 2-39
2.6.7 Groundwater Flow Paths 2-40
2.6.8 Preliminary Conclusions 2-47
2.7 Highway 156 Site Analysis 2-48
2.8 Groundwater Extraction Project Recommendations 2-54
2.9 Recommendations and Next Steps 2-56
Chapter 3 Treatment Technology Assessment 3-1

3.1 Evaluation Criteria 3-1
3.1.1 Product Water Quality 3-1
3.1.2 Water Recovery 3-4
3.1.3 Constituent Removal 3-4
3.1.4 Energy Use 3-4
3.1.5 Waste Stream Management 3-5
3.1.6 Pretreatment and Chemical Addition 3-5
3.1.7 Post-Treatment and Disinfection 3-5
3.1.8 Cost 3-5
3.2 Technology Assessment 3-6
3.2.1 Reverse Osmosis 3-6
3.2.2 Electrodialysis Reversal 3-12
3.2.3 Nanofiltration 3-15
3.2.4 Thermal Distillation 3-17
3.3 Technology Comparison 3-19
3.3.1 Product Water Quality 3-19
3.3.2 Water Recovery 3-19
3.3.3 Constituent Removal 3-19
3.3.4 Energy Use 3-20
3.3.5 Waste Stream Management 3-21
3.3.6 Pretreatment and Chemical Addition 3-21
3.3.7 Post-Treatment and Disinfection 3-22
3.3.8 Costs 3-23
3.3.9 Summary of Comparison 3-23
3.4 Present Worth Economic Evaluation 3-24
3.4.1 BW30-400 Reverse Osmosis System 3-27
3.4.2 XLE-440 Reverse Osmosis System 3-28
3.4.3 NF90-400 Nanofiltration System 3-29
3.4.4 Present Worth Cost Comparison 3-30
3.5 Demineralization Project Recommendations 3-32
3.6 Next Steps 3-35
Chapter 4 Brine Management Assessment 4-1
4.1 Introduction 4-1
4.2 Potential Brine Management Technologies 4-1
4.3 Evaluation Criteria 4-2
4.3.1 Regulatory Considerations 4-2
4.3.2 Technical Considerations 4-2
4.3.3 Water Recovery 4-2
4.3.4 Waste Disposal 4-3
4.3.5 Economic Considerations 4-3
4.4 Technical Evaluation of Brine Management Alternatives 4-3
4.4.1 Evaporation Ponds 4-3
4.4.2 Deep Well Injection 4-9
4.4.3 Disposal to Ocean Outfall 4-14
4.4.4 Product Recovery 4-22
4.4.5 Zero Liquid Discharge 4-24
4.4.6 Vibratory Shear Processes 4-28
4.5 Comparison of Brine Management Alternatives 4-34
4.6 Brine Management Implementation Strategy 4-35
4.6.1 Joint VSEP/Evaporation Pond Brine Management Strategy 4-36
4.6.2 Other Feasible Brine Management Alternatives 4-38

4.7 Conclusions and Next Steps 4-40

Chapter 5 Receiving Water Distribution System Evaluation 5-1

5.1 Potential M&I System Locations 5-1
5.1.1 City of Hollister Urban Area 5-1
5.1.2 City of San Juan Bautista 5-2
5.2 Water Quality and Hydraulic Limitations to Use 5-3
5.2.1 Water Quality Considerations 5-4
5.2.2 Existing Distribution System Capacity 5-4
5.2.3 Storage Requirements 5-6
5.3 Potential Pipeline Alignments 5-6
5.3.1 Distribution Alternatives 5-7
5.3.2 City of Hollister Connection 5-7
5.3.3 City of San Juan Bautista Connection 5-8
5.4 Operational Strategy for Extraction and Treatment 5-8
5.5 Distribution Project Recommendations 5-8
5.6 Next Steps 5-10

Chapter 6 Recommended Plan and Benefit Assessment 6-1

6.1 Recommended Project 6-1
6.1.1 Groundwater Extraction and Conveyance 6-1
6.1.2 Desalination Treatment 6-2
6.1.3 Concentrate Management 6-4
6.1.4 Product Water Storage and Distribution 6-4
6.1.5 Estimated Costs 6-5
6.1.6 Project Cost-Saving Concepts 6-6
6.2 Benefit-Cost Analysis 6-8
6.2.1 Baseline 6-8
6.2.2 Water Supply Options 6-9
6.2.3 Full Range of Benefits and Costs 6-9
6.2.4 Benefit-Cost Comparison 6-12
6.3 Interagency Cost and Benefit Sharing Opportunities 6-13
6.3.1 CVP Water Transfers 6-13
6.3.2 Desalinated Groundwater Transfers 6-17
6.3.3 Groundwater Quality Improvements 6-18
6.3.4 Recycled Water Implementation Opportunities 6-18
6.3.5 CVP Water Availability from Recycled Water Implementation 6-18
6.3.6 Required Interagency Agreements 6-18
6.4 Implementation Strategy 6-19
6.4.1 Financing Strategy 6-19
6.4.2 Major Environmental Considerations & Constraints 6-20
6.4.3 Required Implementation Permits 6-21
6.4.4 Public Outreach Strategy 6-21
6.4.5 Implementation Schedule 6-21
6.5 Coordination with Study Objectives & Goals 6-22

References ....a

List of Tables

Table ES - 1: Overall Project Capital Cost Summary vi
Table ES - 2: Overall Project O&M Cost Summary vi
Table ES - 3: Overall Project Total Cost Summary vii

Table 1-1: Water Year 2005 Water Use in Zone 6 1-11
Table 2-1: San Juan Sub-Basin Pilot Testing Water Quality Analysis 2-2
Table 2-2: Central San Juan Sub-Basin Water Quality Analysis 2-2
Table 2-3: Potential Well Site Summary 2-9
Table 2-4: Groundwater Basin Model Run Summary 2-18
Table 2-5: Groundwater Extraction & Conveyance Facilities [a] 2-54
Table 2-6: Cost Estimate Development Criteria 2-55
Table 2-7: Groundwater Extraction & Conveyance Capital Cost Estimate 2-55
Table 2-8: Groundwater Extraction O&M Cost Estimate 2-56
Table 3-1: Log-Removal Credits for Typical Treatment Technologies 3-3
Table 3-2: Constituents for Removal Efficiency Comparison 3-4
Table 3-3: Demineralization Technology Summary 3-6
Table 3-4: Reverse Osmosis Membrane Summary 3-7
Table 3-5: FILMTEC™ Membrane Removal Efficiencies 3-8
Table 3-6: RO Membrane Energy Use Summary 3-9
Table 3-7: Example EDR Removal Rates 3-14
Table 3-8: NF90-400 Removal Efficiencies 3-16
Table 3-9: Water Recovery Comparison Summary 3-19
Table 3-10: Energy Use Comparison Summary 3-21
Table 3-11: Pretreatment and Chemical Addition Summary 3-22
Table 3-12: Additional Log Removal Credits Required[a] If Source Water Under the Influence of Surface Water[b] 3-23
Table 3-13: Technology Cost Summary 3-23
Table 3-14: Evaluation Ranking Symbols 3-24
Table 3-15: Technology Evaluation Matrix 3-24
Table 3-16: Cost Estimate Design Criteria 3-25
Table 3-17: Unit Capital Costs 3-26
Table 3-18: Unit Operations and Maintenance Costs 3-26
Table 3-19: BW30-400 Flow Summary 3-27
Table 3-20: BW30-400 Present Worth Cost Summary 3-28
Table 3-21: XLE-440 Flow Summary 3-28
Table 3-22: XLE-440 Present Worth Cost Summary 3-29
Table 3-23: NF90-400 Flow Summary 3-29
Table 3-24: NF90-400 Present Worth Cost Summary 3-30
Table 3-25: Present Worth Cost Analysis Summary 3-30
Table 3-26: Energy Cost Sensitivity Analysis ($/hcf) 3-31
Table 3-27: Membrane Replacement Cost Sensitivity Analysis ($/hcf) 3-31
Table 3-28: Recommended RO System Flow Distribution 3-33
Table 3-29: Reverse Osmosis System Process Sizing Summary 3-34
Table 3-30: Demineralization Treatment Capital Cost Estimate 3-34
Table 3-31: Demineralization Treatment O&M Cost Estimate 3-35
Table 4-1: Brine Management Technology Summary 4-1
Table 4-2: Monthly Evapotranspiration and Precipitation Rates 4-6
Table 4-3: Storage Requirements For Varying Water Recoveries and 1.0 MGD of Product Water 4-7
Table 4-4: Estimated Evaporation Pond Costs for 1.0 MGD of Product Water 4-9
Table 4-5: USEPA Injection Well Classifications 4-10
Table 4-6: EPA Permitted Injection Well Operations 4-10
Table 4-7: Injection Well Siting Alternative Benefits & Drawbacks 4-11
Table 4-8: Estimated Injection Well Costs for 1.0 MGD of Product Water 4-14
Table 4-9: Truck Export Design Assumptions for 1.0 MGD of Product Water 4-16

Table 4-10: Estimated Brine Trucking Costs for 1.0 MGD of Product Water....................4-20
Table 4-11: Estimated Multipurpose Pipeline Export Costs for 1.0 MGD of Product Water 4-21
Table 4-12: Estimated Dedicated Pipeline Export Costs for 1.0 MGD of Product Water.4-22
Table 4-13: Summary of Estimated VSEP Costs for 1.0 MGD of Product Water.............4-30
Table 4-14: Revenue Impacts of VSEP Operation....................4-31
Table 4-15: Evaporation Pond Cost Savings for 1.0 MGD of Product Water....................4-31
Table 4-16: Deep Well Injection Cost Savings for 1.0 MGD of Product Water 4-32
Table 4-17: Brine Export via Trucking Cost Savings for 1.0 MGD of Product Water.......4-32
Table 4-18: Brine Export via Multipurpose Pipeline Cost Savings for 1.0 MGD of Product Water 4-33
Table 4-19: Brine Export via Dedicated Pipeline Cost Savings for 1.0 MGD of Product Water 4-33
Table 4-20: Evaluation Ranking Symbols....................4-34
Table 4-21: Brine Management Alternative Evaluation Matrix....................4-35
Table 4-22: VSEP with Evaporation Pond Sizing Summary....................4-36
Table 4-23: Cost Estimate Development Criteria 4-37
Table 4-24: Brine Management Capital Cost Estimate 4-37
Table 4-25: Brine Management O&M Cost Estimate....................4-38
Table 5-1: Existing Hollister Urban Area Water Supply Facilities 5-2
Table 5-2: Selected Hollister Area Water Quality Data 5-2
Table 5-3: City of San Juan Bautista Water Supply Facilities....................5-3
Table 5-4: Selected San Juan Bautista Water Quality Data 5-3
Table 5-5: Proposed Water Distribution System Summary 5-9
Table 5-6: Cost Estimate Development Criteria 5-9
Table 5-7: Distribution Capital Cost Estimate 5-10
Table 5-8: Distribution O&M Cost Estimate....................5-10
Table 6-1: Overall Project Capital Cost Summary 6-5
Table 6-2: Overall Project O&M Cost Summary 6-5
Table 6-3: Overall Project Total Cost Summary....................6-6
Table 6-4: Potential Cost Savings from Deep Well Injection 6-7
Table 6-5: Potential Cost Savings from Higher Flow VSEP with Evaporation Ponds 6-7
Table 6-6: Hollister Area Water Demands....................6-8
Table 6-7: Qualitative Summary of Benefits and Costs....................6-11
Table 6-8: Quantification of Non-Economic Benefits and Costs....................6-12
Table 6-9: Summary of Benefits and Costs 6-13
Table 6-10: CVP M&I Supply and Demand: Current and Following Additional Source of Desalinated SJB Groundwater....................6-16
Table 6-11: Preliminary List of Project Permitting Needs 6-21

List of Figures

Figure ES - 1: Pajaro River Watershed ii
Figure ES - 2: Recommended Project Schematic....................v
Figure ES - 3: Conceptual Wet Year/Dry Year M&I Supply Scenario for the Hollister Urban Area ii
Figure ES - 4: Proposed Implementation Schedule....................iii

Figure 1-1: Pajaro River Watershed 1-2
Figure 1-2: Location Map 1-3
Figure 1-3: San Juan Sub-Basin Location....................1-4

Figure 1-4: Location of Zone 6 and Groundwater Sub-basins....1-12
Figure 1-5: CVP South of Delta Delivery Probability....1-14
Figure 2-1: Hollister Area Groundwater TDS Concentrations (Todd Engineers)....2-3
Figure 2-2: San Juan Valley Groundwater TDS Concentrations (Gus Yates, 2006)....2-4
Figure 2-3: Potential Well Site Locations....2-8
Figure 2-4: San Juan Valley Well Yields....2-10
Figure 2-5: Unit Specific Capacity of San Juan Valley Wells....2-11
Figure 2-6: Hydraulic Conductivity Variations in San Juan Valley....2-12
Figure 2-7: RWQCB Regulated Sites....2-13
Figure 2-8: Agricultural Well Production During Water Year 2004....2-14
Figure 2-9: Drawdown v. Distance Curves for Leaky and Confined Aquifers....2-17
Figure 2-10: Simulation Wellfield and Monitoring Well Locations....2-19
Figure 2-11: Groundwater Elevations at Monitoring Wells - Run 46....2-20
Figure 2-12: Groundwater Elevation Contours - Run 46....2-21
Figure 2-13: Groundwater TDS Concentration Contours - Run 46....2-22
Figure 2-14: Groundwater Elevations at Monitoring Wells – Run 54....2-24
Figure 2-15: Groundwater Elevations at Monitoring Wells - Run 57....2-25
Figure 2-16: Groundwater Elevations at Monitoring Wells - Run 58....2-26
Figure 2-17: Groundwater Elevations at Monitoring Wells - Run 61....2-27
Figure 2-18: San Juan Valley Groundwater Elevation Changes - Run 54....2-29
Figure 2-19: San Juan Valley Groundwater Elevation Changes - Run 57....2-30
Figure 2-20: San Juan Valley Groundwater Elevation Changes - Run 58....2-31
Figure 2-21: San Juan Valley Groundwater Elevation Changes - Run 61....2-32
Figure 2-22: San Juan Valley Groundwater TDS Changes - Run 54....2-34
Figure 2-23: San Juan Valley Groundwater TDS Changes – Run 55....2-35
Figure 2-24: San Juan Valley Groundwater TDS Changes - Run 57....2-36
Figure 2-25: San Juan Valley Groundwater TDS Changes - Run 58....2-37
Figure 2-26: San Juan Valley Groundwater TDS Changes - Run 61....2-38
Figure 2-27: San Juan Valley Groundwater Budgets - Run 54 and Run 58 (1,000 AFY).2-39
Figure 2-28: San Juan Valley Groundwater Budgets - Runs 55, 57 and 61 (3,000 AFY).2-40
Figure 2-29: Horizontal Flow Paths – Run 55....2-42
Figure 2-30: Vertical Flow Paths – Run 55....2-43
Figure 2-31: Horizontal Flow Paths – Run 57....2-44
Figure 2-32: Vertical Flow Paths – Run 57....2-45
Figure 2-33: Horizontal Flow Paths – Run 61....2-46
Figure 2-34: Vertical Flow Paths – Run 61....2-47
Figure 2-35: San Juan Valley Groundwater Elevation Changes – Hwy 156 Location....2-49
Figure 2-36: Horizontal Flow Paths for the Hwy 156 Location....2-50
Figure 2-37: Vertical Flow Paths for Hwy 156 Wellfield....2-51
Figure 2-38: Groundwater Budget Comparison for Hwy 156 Location....2-52
Figure 2-39: San Juan Valley Groundwater TDS Changes for Hwy 156 Location....2-53
Figure 3-1: Reverse Osmosis Vessel Schematic....3-7
Figure 3-2: Pressure Exchanger Operation....3-10
Figure 3-3: EDR Ion Movement....3-13
Figure 3-4: EDR Product & Concentrate Separation....3-13
Figure 3-5: Removal Rate Comparison Summary....3-20
Figure 3-6: General Flow Diagram....3-27
Figure 3-7: Recommended Process Flow Schematic....3-32
Figure 4-1: Evaporation Ponds....4-4
Figure 4-2: Example Injection Well (Laguna County Sanitation District)....4-12
Figure 4-3: Multi Purpose Export Pipeline Schematic....4-18

Figure 4-4: Dedicated Export Pipeline Schematic 4-19
Figure 4-5: Vapor Compression Evaporator 4-25
Figure 4-6: Vapor Compression Solids Crystallizer 4-26
Figure 4-7: Water Recovery Impacts on Brine Management Costs 4-34
Figure 5-1: Regional M&I Water Supply Service Areas 5-1
Figure 5-2: HUAWWMP Recommended Water Supply Facilities....................5-5
Figure 5-3: Conceptual Product Water Connection Infrastructure 5-7
Figure 6-1: Schematic Flow Diagram for Complete Desalination System....................6-3
Figure 6-2: Water Demand and Supply Expansion Scenarios....................6-14
Figure 6-3: Conceptual Wet Year/Dry-Year M&I Supply Scenario for the Hollister Urban Area 6-15
Figure 6-4: Potential Dry Year Transfer Schedule 6-16
Figure 6-5: Potential Near-Term Wet-Year Water Transfer Schedule....................6-17
Figure 6-6: Proposed Implementation Schedule 6-22

Appendices

Appendix A	Drinking Water Source Assessment and Protection Program Documents
Appendix B	Groundwater Model Documentation
Appendix C	Treatment Process Vendor Proposals
Appendix D	Pilot Testing Summary Technical Memorandum
Appendix E	Detailed Technology Comparison Life Cycle Cost Estimates
Appendix F	Title 27 Regulatory Information
Appendix G	Central Coast Regional Water Quality Control Board Form 200-Evaporation Ponds
Appendix H	Evaporation Pond Mass Removal Calculations
Appendix I	Deep Well Injection Feasibility Study Scope
Appendix J	City of Watsonville Wastewater Treatment Plant Discharge Permit Summary
Appendix K	Brine Trucking Cost Estimate
Appendix L	LLNL Brine Assessment Report

List of Abbreviations

ACL	Administrative Civil Liability
AF	acre-feet
AFY	acre-feet per year
BOD	biological oxygen demand
CA	cellulose acetate
CCI	construction cost index
CCR	California Code of Regulations
CCRWQCB	Central Coast Regional Water Quality Control Board
CDPH	California Department of Public Health
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
CIMIS	California Irrigation Management and Information System
CIP	clean in place
CVP	Central Valley Project
CY	cubic yard
DBP	disinfection byproduct
DC	direct current
DFG	Department of Fish and Game
DRIP	Desalination Research and Innovation Partnership
DWR	Department of Water Resources
DWSAP	Drinking Water Source Assessment Program
DWSRF	Drinking Water State Revolving Fund
DWTP	Domestic Wastewater Treatment Plant
ED	electrodialysis
EDC	endocrine disrupting compound
EDR	electrodialysis reversal
EIR	environmental impact report
ENR	Engineering News Record
EPA/USEPA	United States Environmental Protection Agency
ERI	Energy Recovery Inc.
Et_o	reference evapotranspiration
FBRR	Filter Backwash Rate Rule
FIC	Field Induced Charge
gal	gallon
GE	General Electric
GMP	Groundwater Management Plan
GP	Geo Processors
gpm	gallons per minute
GPS	geographical positioning system
GW	groundwater
hcf	hundred cubic feet
HP	horsepower
HUAWWMP	Hollister Urban Area Water and Wastewater Master Plan

IESWTR	Interim Enhanced Surface Water Treatment Rule
in/yr	inches per year
IRWM	Integrated Regional Water Management
IRWMP	Integrated Regional Water Management Plan
IWTP	Industrial Wastewater Treatment Plant
kWh	kilowatt-hour
lb	pound
LCSD	Laguna County Sanitation District
LF	lineal feet
LLNL	Lawrence Livermore National Laboratory
LT1ESWTR	Long Term 1 Enhanced Surface Water Treatment Rule
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
LTWMP	Long Term Wastewater Management Plan
M&I	Municipal and Industrial
MBR	membrane bioreactor
MED	multi effect distillation
MF	microfiltration
MG	million gallons
mg/L	milligrams per liter
μg/L	micrograms per liter
MGD	million gallons per day
μmhos/cm	micromhos per centimeter
MOU	Memorandum of Understanding
MPA	microscopic particulate analysis
MSF	multi-stage flash (distillation)
NA	not applicable
ND	non detect/not developed
NEPA	National Environmental Policy Act
NF	nanofiltration
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity unit
O&M	operations and maintenance
PCAs	possible contaminating activities
PCC	precipitated calcium carbonate
psi	pounds per square inch
PSP	proposal solicitation package
PVWMA	Pajaro Valley Water Management Agency
PX	pressure exchanger
RMC	RMC Water and Environment
RMK	Ridgemark
RO	reverse osmosis
RWQCB	Regional Water Quality Control Board
SAR	sodium adsorption ratio
SBCWD	San Benito County Water District

SBR	sequencing batch reactor
SCVWD	Santa Clara Valley Water District
SDI	silt density index
SDWA	Safe Drinking Water Act
sf	square foot (feet)
SJB	San Juan Valley/San Juan Bautista
SSCWD	Sunnyslope County Water District
SWRCB	State Water Resources Control Board
SWTR	Surface Water Treatment Rule
TCR	Total Coliform Rule
TDH	total dynamic head
TDS	total dissolved solids
TFC	thin film composite
TSS	total suspended solids
UCLA	University of California at Los Angeles
UF	ultrafiltration
UIC	Underground Injection Control
USBR	United States Bureau of Reclamation
USDW	underground sources of drinking water
USGS	United States Geologic Survey
UV	ultraviolet
VC	vapor compression
VSEP	Vibratory Shear Enhanced Process
WDR	Waste Discharge Requirements
WRDA	Water Resources Development Act
WTP	water treatment plant
WWTP(s)	wastewater treatment plant(s)
WY	water year
ZLD	zero liquid discharge

Executive Summary

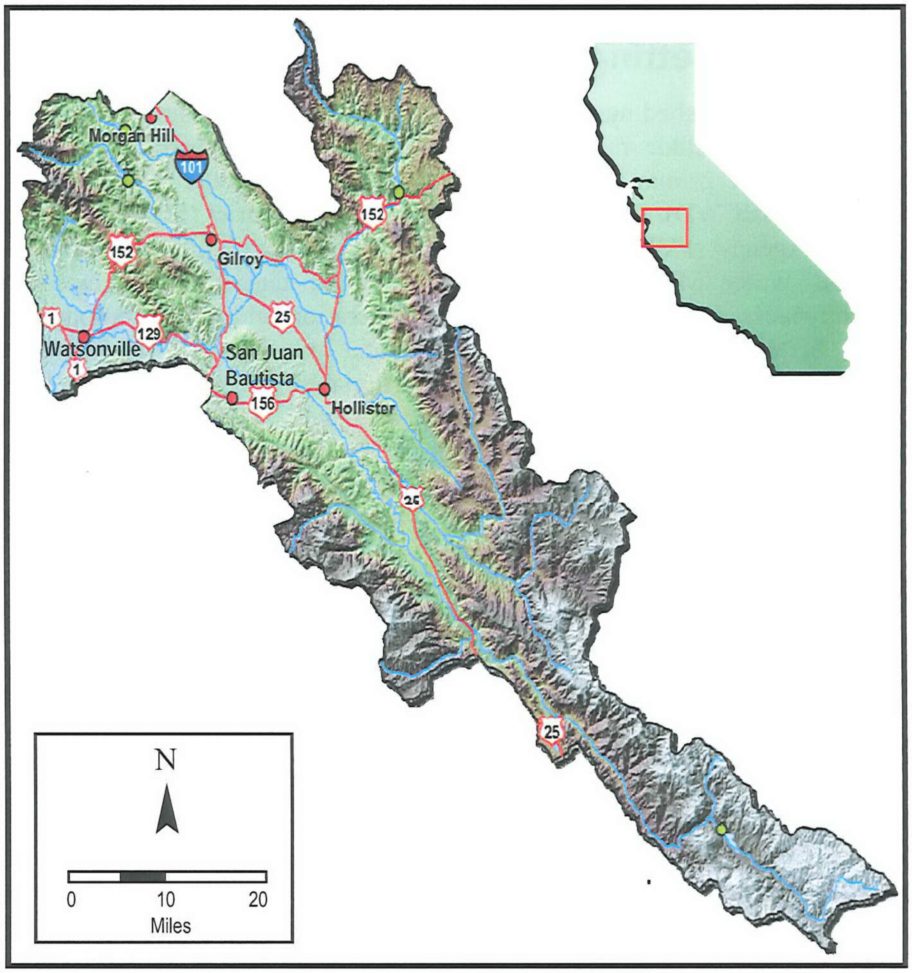
ES-1 Project Setting

Within the Pajaro River Watershed many different types of water users consume water for multiple types of end uses. These uses include residential, agricultural, urban, industrial, open land irrigation and riparian habitat. The three primary water management agencies in the watershed are the San Benito County Water District (SBCWD), the Santa Clara Valley Water District (SCVWD) and the Pajaro Valley Water Management Agency (PVWMA). These three agencies are currently partners in a basin-wide Integrated Regional Water Management (IRWM) program that aims to improve water resource management effectiveness and efficiency, enhance cooperation and collaboration across agencies and stakeholders, and better respond to regional needs and priorities. The Pajaro River Watershed Groundwater Desalination Feasibility Study (Study) is a planning effort by SBCWD and SCVWD, the Project Partners, to identify the technical, economic and institutional benefits and barriers to implementing groundwater desalination in the Pajaro River Watershed. The primary objectives of each agency, as they relate to the Study, are summarized below.

- **SBCWD**
    - Increase water supply reliability
    - Reduce salt load to the groundwater basin
- **SCVWD**
    - Increase water supply reliability
    - Improve dry year supply reliability

Users in the Pajaro River Watershed are served potable water through a combination of groundwater and treated surface water. The water users in the watershed have specific water supply needs including increased reliability during dry years and the ability to enhance their overall supply through the treatment of localized poor quality groundwater. Figure ES-1 shows the geography, the major roadways and major population centers of the Pajaro River Watershed.

Figure ES - 1: Pajaro River Watershed



ES-2 Project Goals and Outcomes

The primary goals and related outcomes of this Feasibility Study are:

1. *Evaluate the feasibility and cost-effectiveness of treating brackish groundwater for potable use: Is a sufficient quantity of information assembled to make a determination of the technical feasibility, economic viability and public acceptance of the desalination project?*
   - Based on the reverse osmosis pilot study and the additional technical information developed during the Study, desalination of brackish groundwater is a technically feasible option for potable water treatment in the Pajaro River Watershed.
   - The cost-benefit assessment identified substantial monetary and non-monetary benefits resulting from the desalination project that are anticipated to show a benefit-cost ratio greater than one.
2. *Assess different treatment technologies and brine management methods to provide the highest level of benefits to the Pajaro River Watershed: Were the best available technologies for brackish groundwater desalination and waste brine management assessed using objective criteria for the specific considerations present in the San Juan Valley?*

   - All of the currently available major desalination technologies (reverse osmosis, nanofiltration, electrodialysis reversal and thermal processes) were assessed using technical, economic and public acceptance criteria to determine the most suitable process for the Pajaro River Watershed as a whole and specifically the San Juan Valley.
   - Traditional and innovative brine management technologies were identified and assessed using objective criteria to establish a current recommendation for brine management as well as areas for additional investigation for the region. Potential cost savings options were also identified for the recommended facilities.

3. *Quantify the offset of Central Valley Project (CVP) water use due to the use of local groundwater as a new, alternative potable water source: What quantity of potable water can be expected to be beneficially used to offset current or projected future CVP water use in San Benito County and what impacts will this have on water reclamation and groundwater sustainability?*
   - Each unit of desalinated groundwater will offset the potential use of one unit of additional imported CVP water in the future. Using the San Juan Valley as a source can reliably and sustainably provide 3,000 acre-feet per year of a new, high quality, reliable potable water supply or San Benito County.
   - The use of this high quality potable water will improve the potential for water reclamation as the dissolved salt loading into the wastewater system would be reduced both from the reduction in salts in the potable water and the decreased need for in-home water softeners.
   - The removal of salts from the groundwater basin through final disposal of the waste brine will, over time, increase the overall quality of the groundwater and result in a higher value resource.
4. *Identify benefits and mechanisms to transfer and assure equitable benefits throughout the Pajaro River Watershed as well as the State and the Bay-Delta system: Does the project provide significant benefits to the Project Partners? Can local benefits from the groundwater desalination project create benefits for other watershed partners as well as the State and the Bay-Delta water supply system and are these benefits sufficient to provide continued interest in the project from the beneficiaries?*
   - The monetary project benefits include capping salt imports to the Sub-Basin and reducing the need for additional CVP deliveries. These benefits have been estimated to offset about 60% of the estimated project costs. The Project Partners (SBCWD, SCVWD and DWR) are significant beneficiaries of the project while other local entities may realize additional benefits from the implementation of groundwater desalination from the San Juan Valley.
   - The non-monetary benefits are significant and, at this feasibility level of study, result in an overall benefit-cost ratio greater than one.
   - The local benefits of an additional water supply with increased reliability and local control allow for the potential reduction in use of CVP water. A reduction in use would allow for more water available to the Bay-Delta habitat or could potentially allow for wet-to-normal and dry year CVP water transfers to regional water suppliers, such as SCVWD. The prospect of additional high quality dry year water supply provides an opportunity to help meet an identified long-term objective for SCVWD and other regional water agencies and is anticipated to maintain regional interest in the project.
5. *Provide the basis for future demonstration and full-scale project implementation projects in the San Juan Sub-Basin to yield roughly 3,000 acre-feet per year of new water supply: Will the recommended project be ready to move into subsequent phases that will continue to move towards implementation of a new water supply for the Pajaro River Watershed?*

  - The recommended project identifies a combination of facilities that will enable the next implementation step to be taken toward developing a new supply for the Pajaro River Watershed. The next identified step is to further evaluate the alternative brine management strategies that have the potential to reduce costs and provide additional benefits for the project partners and water users. Other specific next steps include well site identification and "proof" pilot testing of specific reverse osmosis membranes on water drawn from an identified well site.
  - The San Juan Valley groundwater desalination facility was also identified in the Hollister Urban Water and Wastewater Master Plan as a recommended facility and implementation of this project is planned to be in conjunction with the implementation of the other recommended elements of the Master Plan.

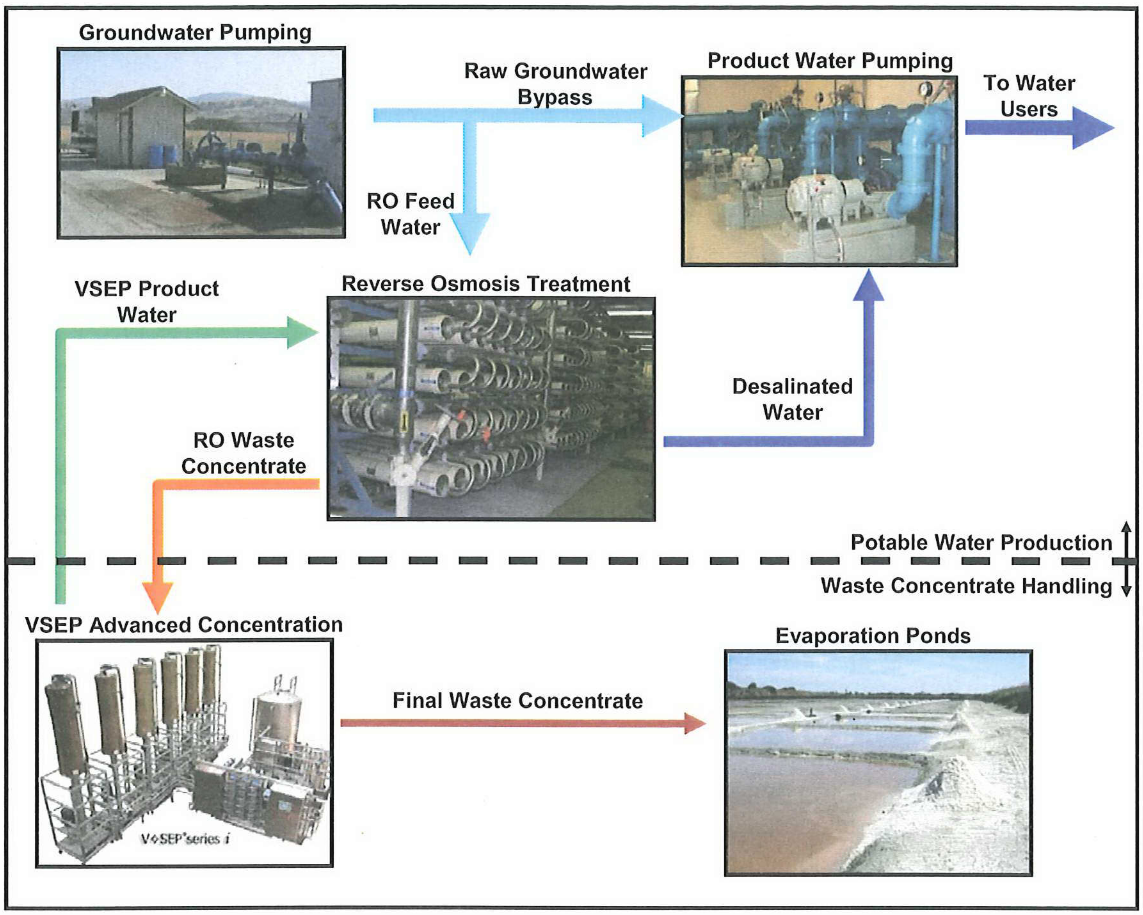
ES-3 Project Recommendations

Based on the results of the technical evaluation described in Chapter 2 through Chapter 5 of the Feasibility Study the recommended San Juan Valley desalination project would consist of four elements:

- **Groundwater extraction and pumping** – A series of six deep wells, screened from 150 to 500 feet below the ground surface, would provide the capacity to pump 3,065 acre-feet per year (AFY) of groundwater to supply the desalination treatment facility. This quantity of water assumes a very high water recovery through the desalination and advanced brine concentration processes, estimated at 98% water recovery. If actual water recoveries were lower, the total pumping would need to be increased accordingly but should not exceed the maximum sustainable extraction from the San Juan Valley, estimated at approximately 4,300 AFY. The wells are proposed to be located in the general vicinity of Highway 156 between Lucy Brown Lane and Bixby Road.
- **Desalination treatment** – Approximately 2.4 million gallons per day (MGD) of reverse osmosis product water would be blended with approximately 0.3 MGD of raw groundwater to produce 3,000 AFY of high quality potable water for the Hollister Urban Area. The RO product water would be treated through low pressure reverse osmosis membranes to achieve a water recovery of approximately 83%. The blended water would meet the total dissolved solids (TDS) and hardness goals established by the Hollister Urban Area Water and Wastewater Master Plan (HUAWWMP) of 500 mg/L TDS and 120 mg/L hardness.
- **Waste concentrate management** – The waste concentrate from the RO process would then be further treated using an advanced concentration process such as the Vibratory Shear Enhanced Process (VSEP) to reduce the total volume of waste concentrate from 0.5 MGD to approximately 0.05 MGD. This final waste material for disposal would represent only 2% of the influent groundwater, greatly reducing the quantity of waste for final disposal. Following this processing step, the waste product is planned to be dried in evaporation ponds where the remaining solids would be periodically removed and disposed in a suitable landfill.
- **Product water storage and pumping** – The blended product water is planned to be supplied to the Hollister Urban Area water distribution system, which also provides a significant quantity of storage for the potable water. A 0.9 million gallon storage facility is planned to be incorporated at the demineralization facility to facilitate routine maintenance on the membrane system and meet peak water demands. The 3,000 AFY of potable water would be provided to the Hollister Urban Area through a dedicated pump station to provide suitable pressure in the distribution system. Future provisions to provide water to the City of San Juan Bautista would be incorporated into the design.

Figure ES-2 shows a schematic representation of the recommended project.

Figure ES - 2: Recommended Project Schematic



ES-4 Recommended Project Costs

The brackish groundwater desalination system described in the previous section has an estimated cost summarized in Table ES-1, Table ES-2 and Table ES-3 The proposed facility would produce 3,000 AFY of groundwater (desalinated groundwater blended with untreated groundwater) for potable water use resulting in a total unit cost of approximately $2,200/AF in 2007 dollars, and approximately $2,900/AF projected to 2014 costs.

Table ES - 1: Overall Project Capital Cost Summary

Project Element	TOTAL CAPITAL COST (2007)	Annualized Capital Cost (2007)	TOTAL CAPITAL COST (2014)	Annualized Capital Cost (2014)
Groundwater Extraction & Conveyance	$6,000,000	$400,000	$7,900,000	$500,000
Desalination Treatment	$6,500,000	$400,000	$8,600,000	$600,000
Concentrate Management (VSEP plus ponds)	$25,100,000	$1,700,000	$32,800,000	$2,100,000
Product Water Storage and Distribution	$13,900,000	$900,000	$18,100,000	$1,200,000
TOTAL PROJECT	**$51,500,000**	**$3,400,000**	**$67,400,000**	**$4,400,000**

Table ES - 2: Overall Project O&M Cost Summary

Project Element	TOTAL ANNUAL O&M COST (2007)	Present Worth O&M Cost (2007)	TOTAL ANNUAL O&M COST (2014)	Present Worth O&M Cost (2014)
Groundwater Extraction & Conveyance	$100,000	$1,600,000	$100,000	$2,100,000
Desalination Treatment	$400,000	$6,600,000	$600,000	$8,600,000
Concentrate Management (VSEP plus ponds)	$2,500,000	$37,600,000	$3,200,000	$49,100,000
Product Water Storage and Distribution	$300,000	$4,900,000	$400,000	$6,500,000
TOTAL PROJECT	**$3,300,000**	**$50,700,000**	**$4,300,000**	**$66,300,000**

Table ES - 3: Overall Project Total Cost Summary

Project Element	TOTAL ANNUAL COST (2007)	TOTAL PRESENT WORTH COSTS (2007)	TOTAL ANNUAL COST (2014)	TOTAL PRESENT WORTH COSTS (2014)
Groundwater Extraction & Conveyance	$500,000	$7,700,000	$600,000	$10,000,000
Desalination Treatment	$900,000	$13,100,000	$1,200,000	$17,100,000
Concentrate Management	$4,100,000	$62,700,000	$5,300,000	$81,900,000
Product Water Storage and Distribution	$1,200,000	$18,800,000	$1,600,000	$24,600,000
TOTAL PROJECT	**$6,700,000**	**$102,300,000**	**$8,700,000**	**$133,600,000**

To help reduce these project costs, several alternatives could be considered:

- Implementing deep well injection for concentrate disposal could result in a savings of approximately $1,250 per acre-foot of water produced and could potentially reduce implementation obstacles such as land acquisition and permitting.
- Increasing the flux rate on the VSEP units to twice the current estimates. This would significantly reduce the required investment for this project element and would decrease the overall maintenance requirements for the facility. This flux rate would need to be confirmed via bench-scale or pilot testing and, if feasible, could provide a savings of $330 per acre-foot.
- The large quantity, more than 6,000 tons per year, of solids removed from the groundwater may have the potential to generate marketable products that will assist in offsetting the overall facility cost and would reduce the quantity of salts for final disposal. Further detailed investigation into the potential for recovery using chemically enhanced recovery systems is required to provide an estimate on the potential savings.

ES-5 Recommended Project Benefits

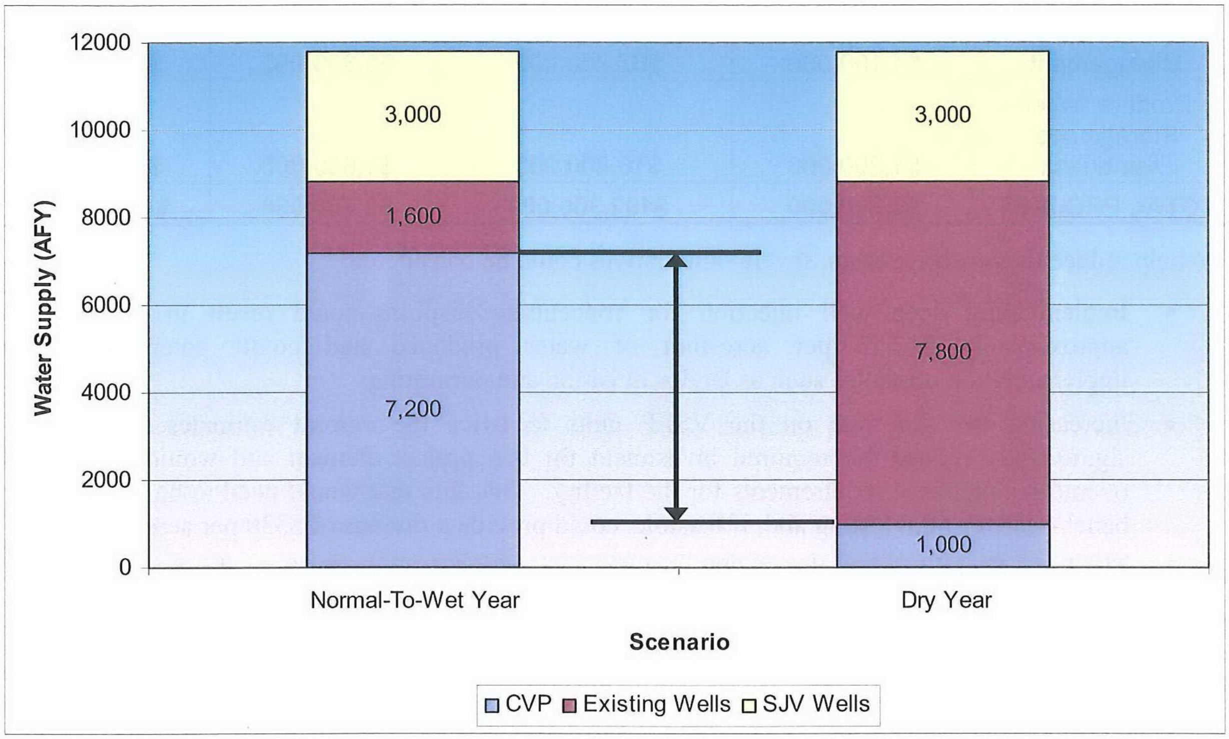
The desalination project would provide several categories of benefits for the Pajaro River Watershed including:

- Diversifying water supply sources
- Increasing local control of the water supply
- Improving potable water quality
- Avoiding costs for acquisition of additional imported water supplies
- Managing high groundwater levels
- Improving groundwater quality
- Capping salt imports to the region
- Providing opportunities for regional water transfers
- Preserving the Bay-Delta habitat

Of these benefits, capping of salt imports and avoiding costs associated with acquiring additional import water supplies represent $5.0 million to $5.3 million in annual benefits. These two benefits alone offset nearly 60% of the project costs.

Partnership opportunities for a project of this magnitude and cost would further enhance its implementability. The primary partnership identified for this project would be through CVP water transfers between SBCWD and SCVWD or PVWMA. Accelerated implementation of the desalination facility would provide SBCWD the opportunity to transfer a portion of their CVP municipal and industrial (M&I) supply on a temporary basis. SCVWD, as a current CVP contractor with an existing connection to the system, is interested in dry year supplies to further improve the reliability of their water supply portfolio. This could be accomplished by use of CVP water in the San Benito area during normal-to-wet hydrologic years, allowing the groundwater basins to fill up, effectively banking this water for use in dry years. During these dry years, SBCWD could utilize this banked groundwater through demineralization and transfer the unused CVP water to SCVWD for their use. Figure ES-3 shows this potential transfer mechanism for projected Hollister Urban Area demands for 2023.

Figure ES - 3: Conceptual Wet Year/Dry Year M&I Supply Scenario for the Hollister Urban Area

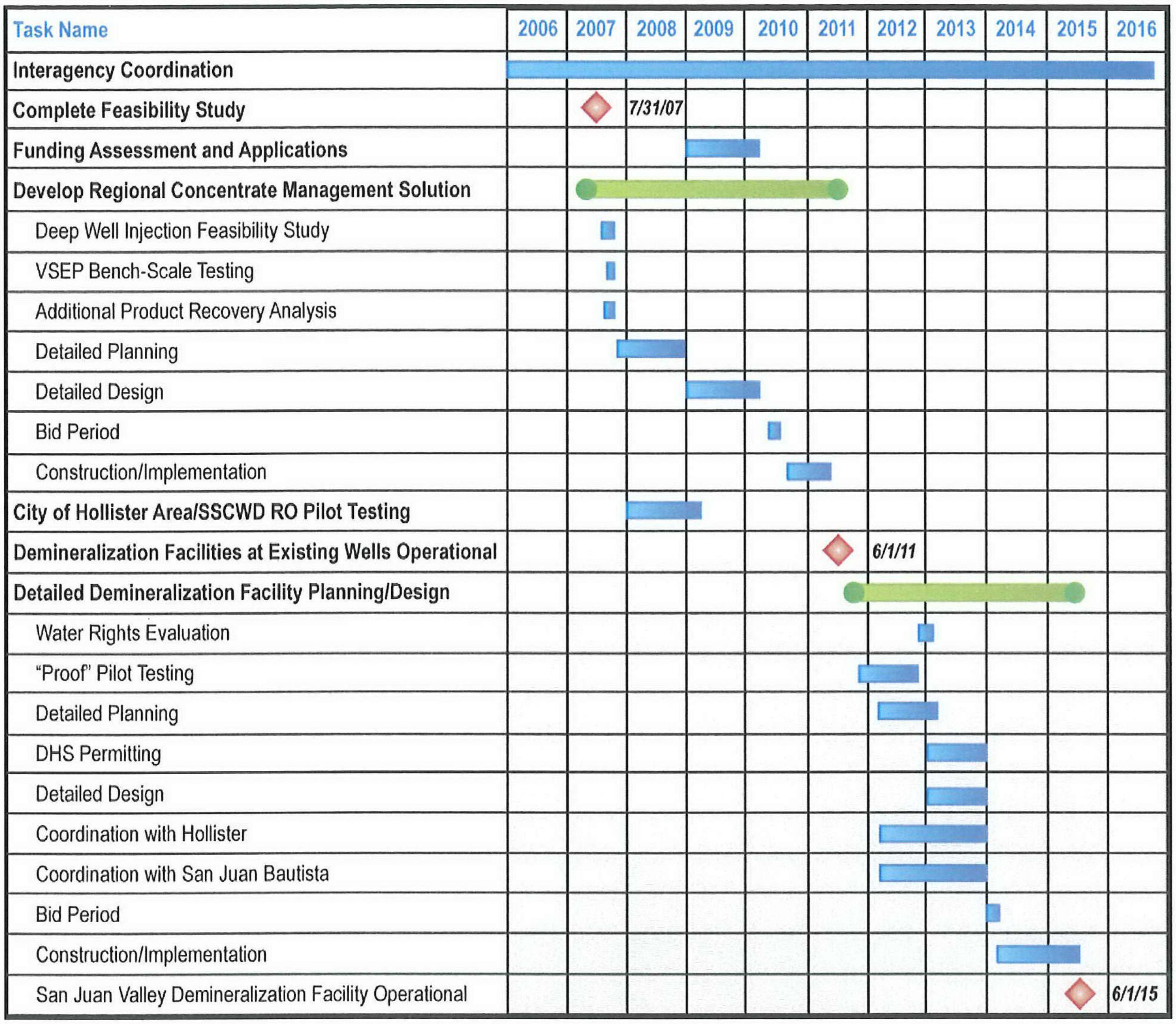


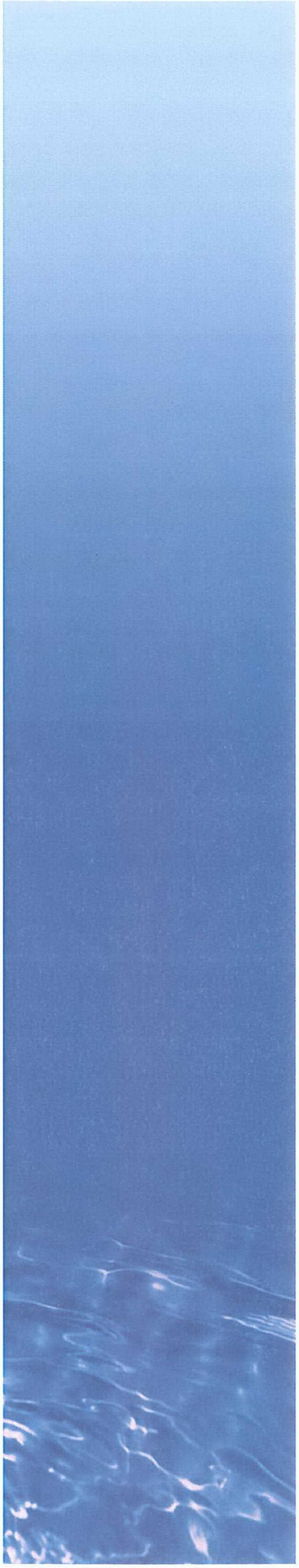
Additional transfer opportunities are potentially available during wet years. Both wet and dry year transfer agreements should be explored in more depth to further the regional partnership opportunities.

ES-6 Project Implementation

Further implementation of the San Juan Valley groundwater desalination project is contingent on the schedule identified in the Hollister Urban Water and Wastewater Master Plan. Current projections indicate that the facility would be needed by 2015 to meet water demands in the area. Achievement of this implementation date would require a regional concentrate management solution to be in place first. Concentrate management for the region is currently identified to be completed in conjunction with desalination of the existing Hollister Urban Area water supply wells which is summarized in the schedule shown in Figure ES-4.

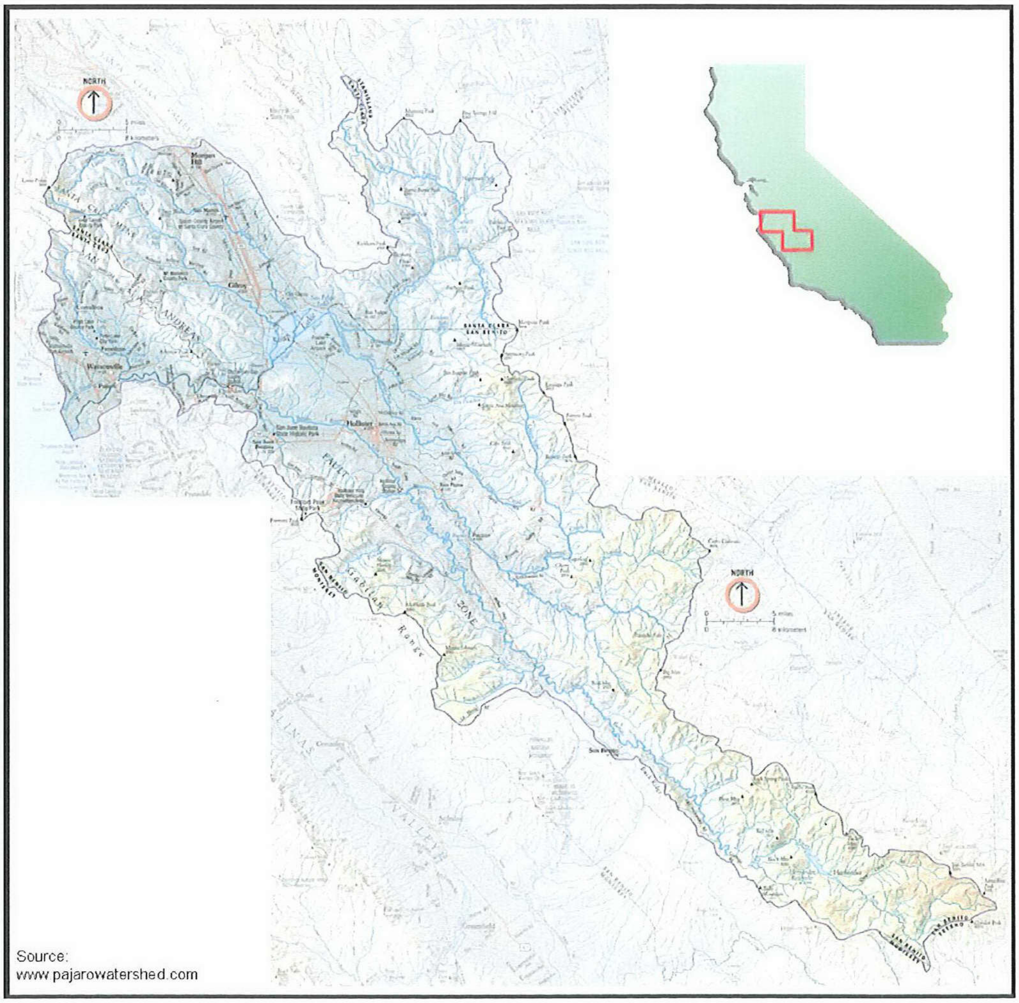
Figure ES - 4: Proposed Implementation Schedule





Chapter One

Project Setting



Source:
www.pajarowatershed.com

Chapter 1 Project Setting

1.1 Project Background

The overall goal of this feasibility study is to evaluate the feasibility for implementation of either a demonstration project or a full-scale project to extract, treat and deliver groundwater to a municipal and industrial (M&I) supply system. The San Benito County Water District (SBCWD) and the Santa Clara Valley Water District (SCVWD; Project Partners) have entered into a memorandum of understanding to jointly study opportunities to improve water supply reliability within the Pajaro River watershed.

The Pajaro River watershed drains northern San Benito County and southern Santa Clara County, via the Pajaro River, through portions of Monterey and Santa Cruz Counties. In addition to this common watershed, the Agencies share an imported water supply via the Central Valley Project's (CVP) San Felipe Division. A sub-basin within the upper watershed, San Juan Sub-Basin, has poor quality groundwater. A significant portion of the San Juan Sub-Basin has total dissolved solids (TDS) concentrations in excess of 1,000 milligrams per liter (mg/L) and is impaired as a beneficial water supply. Through an integrated regional water management planning effort, the Project Partners have identified this high TDS groundwater as a potential new M&I water source and wish to perform a feasibility study of this water supply opportunity.

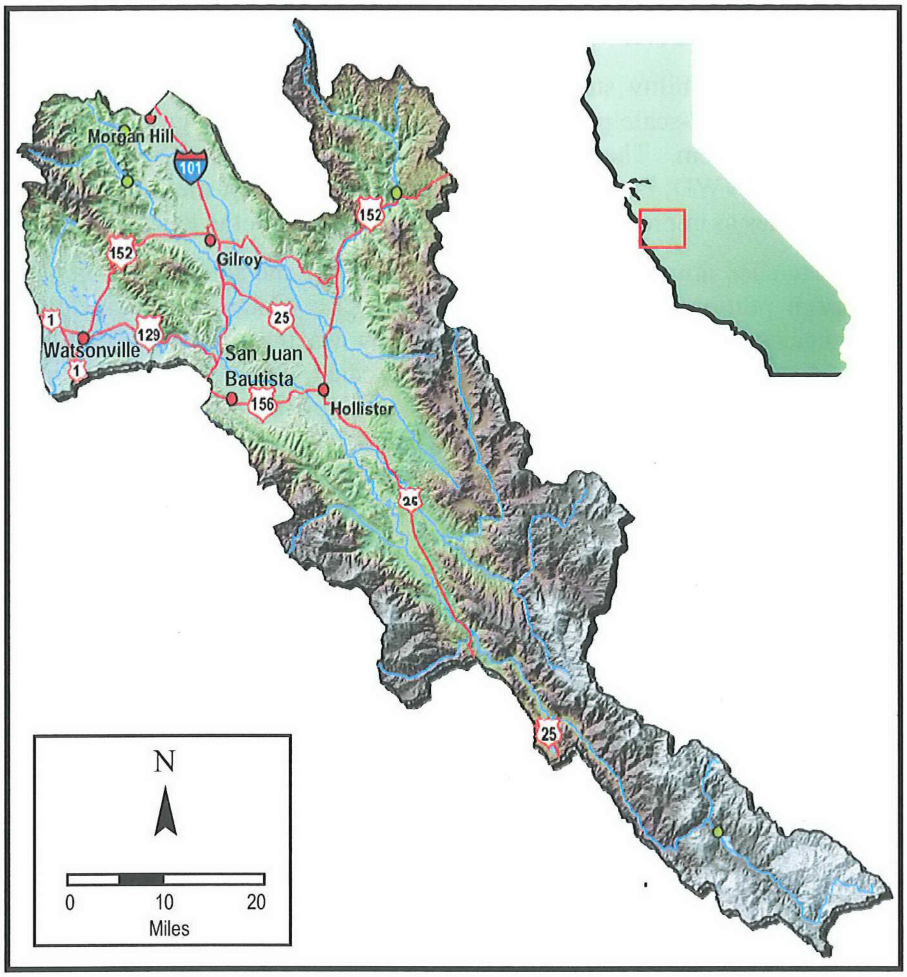
A Pajaro River Watershed groundwater demineralization facility will provide a number of potential benefits to the region as well as individual benefits to the Project Partners. These benefits could become an integral part of Pajaro Watershed Integrated Regional Water Management Plan (IRWMP) implementation process. A preliminary list of these benefits includes:

- creates a new potable water supply,
- offsets imported CVP water supply,
- reduces levels of TDS in treated wastewater enabling expansion of local water recycling, and
- provides additional environmental and wastewater effluent management benefits.

1.1.1 Project Location

The Pajaro River watershed is located in northern California and stretches from Fresno County in the south to within several miles of San Jose in the north. The watershed covers an area of approximately 1,300 square miles and includes portions of four counties. Figure 1-1 shows the extent of the watershed and identifies many of its major features including major cities, major highways and natural geography.

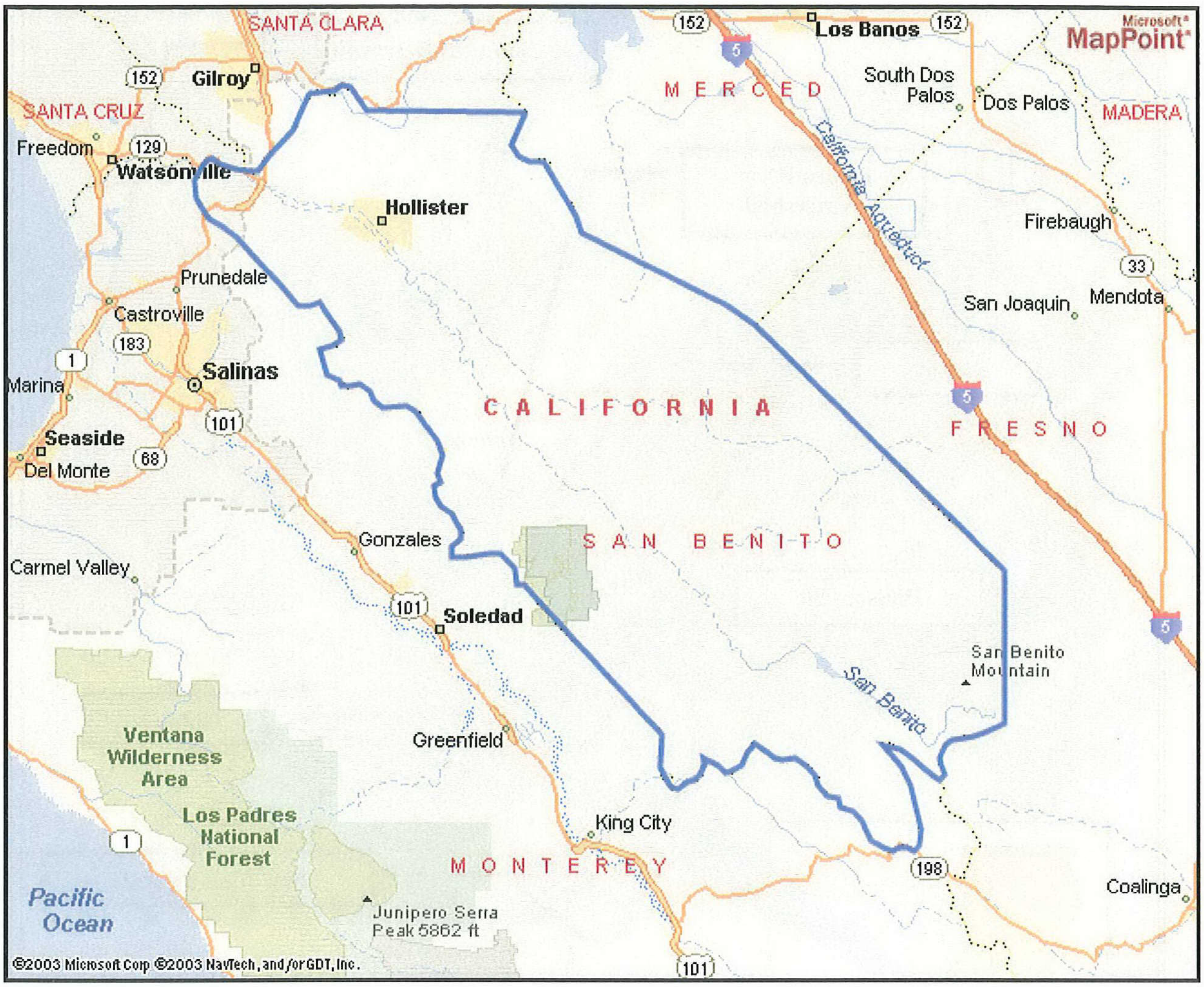
Figure 1-1: Pajaro River Watershed



Several water management agencies have jurisdiction over portions of the Pajaro Watershed, including SBCWD, SCVWD and the Pajaro Valley Water Management Agency (PVWMA). These agencies are partners in several ongoing efforts including the Pajaro Watershed IRWMP (described in more detail in Section 1.3) which is in the process of identifying regional projects and potential areas for coordination of water resources management within the watershed.

San Benito County (County) encompasses an area of nearly 1,400 square miles and is located in California's Central Coast region approximately 40 miles south of San Jose and 45 miles northeast of Monterey. The County is bordered by Santa Clara County to the north, Monterey County to the south and west, Merced County to the east, and Fresno County to the south and east (see Figure 1-2). Most of the 56,000 County residents live in or near Hollister and San Juan Bautista. All of the existing wastewater treatment facilities and several major agricultural areas are adjacent to Hollister and San Juan Batista, in the northern portion of the County.

Figure 1-2: Location Map

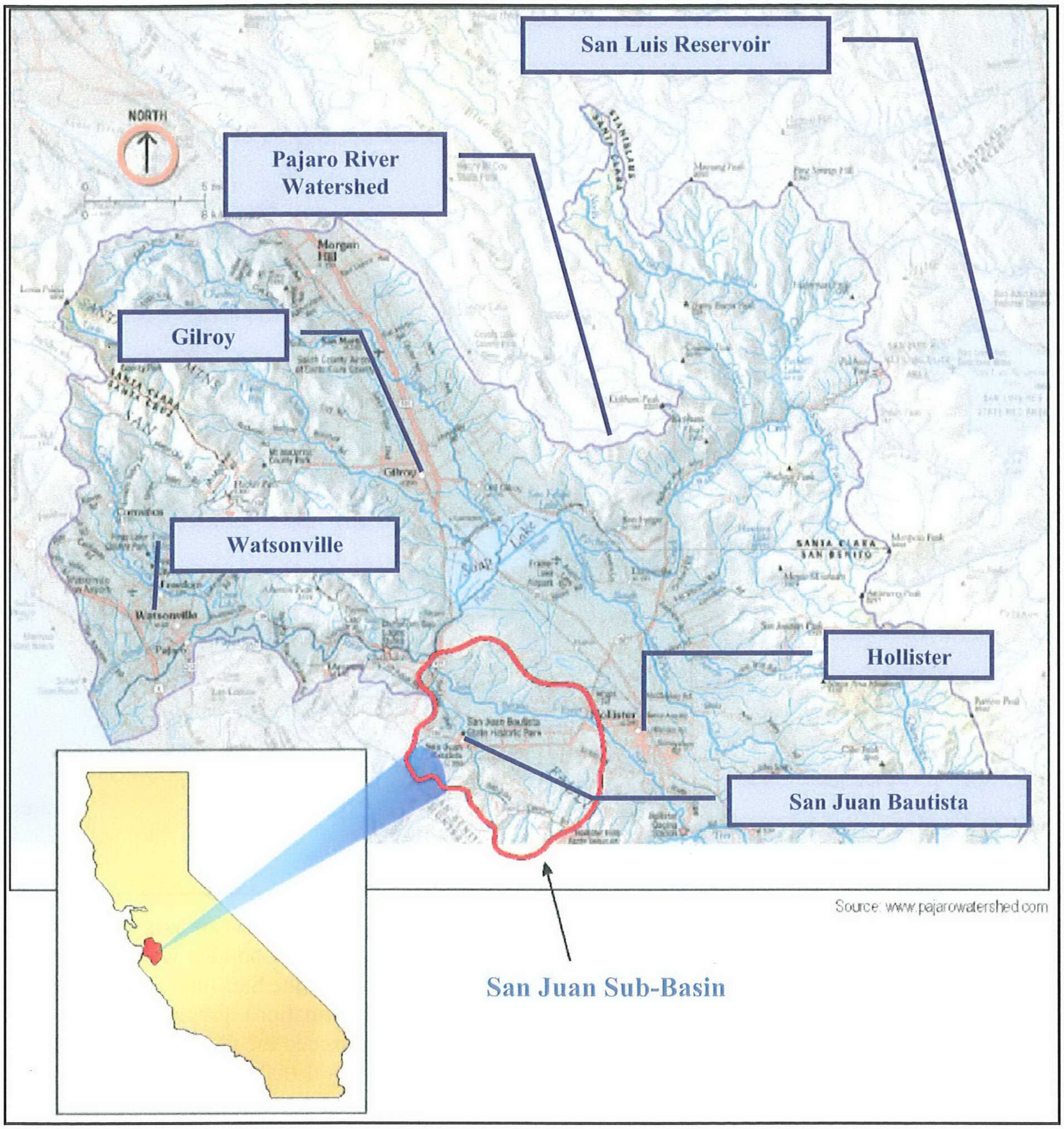


This feasibility study focuses on the San Juan Valley and the San Juan Sub-Basin as a potential water source for a groundwater desalination treatment facility that could provide a potable water supply to the greater San Juan Bautista/Hollister area. Figure 1-3 shows the location of the San Juan Basin. This water would be treated through a demineralization (also known as desalination) process. Much of the groundwater in the San Juan Sub-Basin has TDS concentrations that exceed the California Department of Public Health (CDPH) secondary standard for drinking water of 500 – 1,000 mg/L[1]. In some locations within the San Juan Sub-Basin, the TDS concentration of the groundwater exceeds 1,500 mg/L, the short-term limit for drinking water set by CDPH.

---

[1] Variability in standards reflect the recommended limit and the upper limit. Additionally, a short-term limit of 1,500 mg/L has been established.

Figure 1-3: San Juan Sub-Basin Location



Source: www.pajarowatershed.com

1.1.2 Project History

Development in northern San Benito County throughout the 20th century has placed an increased demand on the region's water supplies. Municipal, industrial and agricultural activities in San Benito County and southern Santa Clara County historically relied upon groundwater as the primary source of water supply. This continued increase in groundwater use resulted in a significant drawdown of the groundwater aquifers in San Benito County and southern Santa Clara County. This drawdown resulted in increased pumping costs and a need for deeper wells. Additionally, the groundwater that was available was high in naturally occurring salts, and through the addition of salts through agricultural and urban practices, groundwater quality was degrading.

In response to the water supply issues facing the residents of San Benito and Santa Clara Counties, the United States Bureau of Reclamation (USBR) undertook the planning and development of the San Felipe Division of the Central Valley Project (CVP), and published the San Felipe Division Feasibility Report in 1963. The San Felipe Division takes water from the San Luis Reservoir, where it is pumped through a tunnel, conduit and pipe system that provides CVP water to customers in San Benito and Santa Clara Counties through facilities operated by the San Benito County Water District (SBCWD) and the Santa Clara Valley Water District (SCVWD), respectively. From the turnout on the San Felipe system, SBCWD operates 120 miles of pressurized distribution pipelines to serve CVP water to agricultural and municipal customers. In addition, SBCWD operates San Justo Reservoir, which provides 11,000 acre-feet of storage for CVP water. The SCVWD operates recharge, treatment and distribution facilities to deliver CVP water to agricultural, municipal and industrial customers in Santa Clara County. The San Felipe Division was implemented and CVP water deliveries were initiated in 1987.

The CVP water in the San Felipe Division must be pumped through a total hydraulic lift of 309 feet through the Pacheco Pumping Plant. For one acre-foot of water, this lift requires approximately 316 kilowatt-hours (kWh) of energy. At a cost of $0.03/kWh, the cost of in-system CVP power, each acre-foot requires approximately $10 in energy to be delivered to the Pajaro River Watershed. Typical electricity rates of $0.15/kWh would result in energy costs approaching $50/acre-foot (AF) for delivery to the San Felipe distribution system.

The CVP water supply is considered high quality (250 mg/L TDS). This high quality imported water provides numerous significant benefits to water users in San Benito and Santa Clara Counties, including improved water quality, reduced groundwater pumping and restoration of groundwater levels. However, the use of any imported water for any use results in an additional salt loading to the local area.

The Gilroy-Hollister groundwater basin in southern Santa Clara and northern San Benito Counties has a single outflow mechanism, seepage into and surface water flow through the San Benito and Pajaro Rivers. Depending on the groundwater level, the basin can function as a closed basin. When water levels are low, there is no seepage and the basin is closed. This was the situation during the 1950s through the 1980s when the basin was significantly overdrafted. Currently, the basin is not functioning as a closed basin, due to the decreased pumping as a result of the use of CVP water for agricultural irrigation, and excess groundwater can be discharged through the river systems. This discharge only accounts for a relatively small volume of the groundwater (11,000 acre-feet per year [AFY] in water year 2005) and salts continue to accumulate in the groundwater basin, continuing the decline in groundwater quality. This decline in groundwater quality threatens the sustainability of groundwater as a water supply for the region.

Two primary alternatives have been examined to provide high quality potable water to the SBCWD service area: importing additional water for treatment, distribution and demineralization of local groundwater. This Groundwater Desalination Feasibility Study was identified in the SBCWD July 2003 Groundwater Management Plan (GMP) Update as a high priority project necessary to address long-term potable water supplies and the continued accumulation of salts in the groundwater basin. In October 2004, the California Department of Water Resources (DWR) released a Proposal Solicitation Package (PSP) for twenty-five million dollars in grant funding under Proposition 50, Chapter 6a. This chapter provides "grants for construction projects, as well as research and development, feasibility studies, and pilots and demonstration projects" for the desalination or demineralization of brackish groundwater or seawater. The combination of the need for the project identified in the GMP and the funding available through DWR pushed this study to the forefront of the water supply arena in San Benito County.

The SBCWD and the SCVWD agreed to jointly pursue funding for the Groundwater Desalination Feasibility Study. Both agencies receive imported water through the San Felipe Division, both rely on local groundwater supplies that are impacted to varying degrees by high salt levels, and both are seeking increased reliability in their water supply portfolios, providing a common set of issues of interest in the results of the Groundwater Desalination Feasibility Study. These linkages, in conjunction with other previous partnerships, brought the two agencies together as the Project Partners.

The Project Partners then completed and submitted a proposal package for the Proposition 50 grant program. The final funding list was announced in May 2005 with this study being ranked the highest feasibility study submitted for consideration. The Project Partners were awarded a $245,000 grant to fund this feasibility study, while contributing an additional $245,000 in monetary and "in-kind" services to fulfill the financial match requirements of the grant program. A contract was signed between SBCWD and DWR in February 2006 and the Project Partners retained RMC Water and Environment (RMC) to complete the Feasibility Study. The goals of this Study are identified in Section 1.2.

1.2 Goals and Objectives

The goals and objectives for the Pajaro River Watershed Groundwater Desalination Feasibility Study were first developed in 2005. They were further refined in early 2006, and are summarized below.

1.2.1 Feasibility Study Goals

As delineated in the DWR Funding application, this Feasibility Study will have five main goals, each with its own measurement of success. These five goals and their measurement criteria are:

1. Evaluate the feasibility and cost-effectiveness of treating brackish groundwater for potable use:
    - Is a sufficient quantity of information assembled to make a determination of the technical feasibility, economic viability and public acceptance of the desalination project?
2. Assess different treatment technologies and brine management methods to provide the highest level of benefits to the Pajaro River Watershed:
    - Were the best available technologies for brackish groundwater desalination and waste brine management assessed using objective criteria for the specific considerations present in the San Juan Valley?
3. Quantify the offset of CVP water use due to the use of local groundwater as a new, alternative potable water source:
    - What quantity of potable water can be expected to be beneficially used to offset current or projected future CVP water use in San Benito County and what impacts will this have on water reclamation and groundwater sustainability?
4. Identify benefits and mechanisms to transfer and assure equitable benefits throughout the Pajaro River Watershed as well as the State and the Bay-Delta system:
    - Does the project provide significant benefits to the Project Partners?
    - Can local benefits from the groundwater desalination project create benefits for other watershed partners as well as the State and the Bay-Delta water supply system and are these benefits sufficient to provide continued interest in the project from the beneficiaries?
5. Provide the basis for future demonstration and full-scale project implementation projects in the San Juan Basin to yield roughly 3,000 acre-feet per year of new water supply:
    - Will the recommended project be ready to move into subsequent phases that will continue to move towards implementation of a new water supply for the Pajaro River Watershed?

1.2.2 Potential Implementation Projects

The objective of this Feasibility Study is to identify and provide a basis for future implementation projects in the Pajaro River Watershed. These potential implementation projects have their own set of goals and objectives that will be clarified and further refined throughout the Feasibility Study and potential future phases. The initial goals and objectives for these implementation projects are:

- To provide a high quality water supply for the Pajaro River Watershed
- To provide the ability to offset the use of low-quality groundwater and/or the use of imported, less than fully reliable CVP water
- To provide a beneficial means of removing salt from the water supply and by extension the groundwater basin, wastewater treatment system and wastewater disposal system
- To provide an additional method to control groundwater levels in the Pajaro River Watershed
- To convert a minimally used water supply to a potable municipal water source

1.3 Concurrent Projects

The SBCWD service area has many planning and design projects currently in progress. Many of these projects have potential coordination elements with this Study. A summary of these projects follows.

Pajaro River Watershed Integrated Regional Water Management Plan (IRWMP)

The Pajaro River Watershed Integrated Regional Water Management Plan (IRWMP) has been developed through the efforts of a three-agency collaborative of the PVWMA, SBCWD and SCVWD, along with numerous watershed stakeholders. The Plan was adopted by all agencies in May and June 2007.

The goals of this plan are to provide integrated, regional solutions to water supply, water quality, flood protection and environmental protection challenges in the Pajaro River Watershed. The groundwater demineralization project has been identified as an integral part of this overall plan as it helps to fulfill both water supply and water quality goals. Other projects, such as the PVWMA Import or Multi-Purpose Pipeline, that are potentially part of this plan will provide potential collaborations for groundwater desalination. The Multi-Purpose Pipeline would potentially provide concentrate export options for the San Benito and southern Santa Clara areas, and could benefit any project to be implemented from this Feasibility Study. Additionally, water transfers and intra-region water banking are anticipated to provide a means of transferring benefits from a groundwater demineralization project in the San Benito area throughout the entire Pajaro River Watershed.

City of Hollister Urban Water and Wastewater Master Plan

A 2004 Memorandum of Understanding (MOU) was signed by the City of Hollister, San Benito County and SBCWD to govern the development process for the Hollister Urban Area Water and Wastewater Master Plan (HUAWWMP). The 2004 HUAWWMP MOU identified water quality objectives for both potable water and recycled water for irrigation uses. These two water qualities are very closely linked through the wastewater collection and treatment system because achievement of the recycled water quality goal will require advanced wastewater treatment in the absence of potable water quality improvements.

The HUAWWMP is intended to integrate water supply, wastewater treatment and wastewater disposal into a single document. The HUAWWMP was completed in early 2007. The major goals of the plan are to identify means to:

- Provide potable water customers a consistent supply of high quality potable water
- Produce a treated wastewater effluent that will be suitable for widespread urban and agricultural irrigation with minimal additional treatment
- Integrate surface water and groundwater management activities to provide the means to achieve groundwater management objectives through flexibility in the use of both sources

A groundwater demineralization facility is a project that would assist in reaching all three of these goals. The facility would:

- Produce water that would meet or exceed the established potable water quality goals on a reliable basis
- Reduce the mass loading of salt to the wastewater treatment and disposal system, thereby helping to achieve a recycled water quality that is suitable for irrigation uses
- Provide a new water supply to further diversify the water supply portfolio of the region

Desalination Research & Innovation Partnership (DRIP) Project

Dr. Martin Reinhard, of the Department of Civil and Environmental Engineering at Stanford University, is currently collaborating with SCVWD in a study performed under the Desalinization Research and Innovation Partnership (DRIP), administered through the Metropolitan Water District of southern California.

The DRIP program is an investigation of the technical and economic feasibility of desalinization as a means to assist the State of California in providing sufficient quantities of water to satisfy its growing demands. The current work performed by Stanford University researchers has three main objectives:

- To determine if reverse osmosis (RO) treatment of brackish groundwater is economically feasible for SCVWD. This will be established using pilot test units and a post-study economic analysis incorporating data on operations and maintenance to evaluate the feasibility of a full-scale system.
- To evaluate and compare the performances of novel RO membranes under field conditions with respect to permeate flux, removal efficiencies for trace organics and resistance to fouling. One pilot system will be designed to accommodate up to four different types of membranes in parallel configuration, so that the membranes can be tested simultaneously but independent of each other.
- To conduct membrane fouling studies on state-of-the-art and novel membranes after being subjected to field conditions. Provisions of this research include field testing of the pilot desalinization units at up to four locations. One location has been chosen in northern Santa Clara County. As part of the Pajaro Watershed Groundwater Desalinization Feasibility Study, one of these final three pilot test locations will be located in the San Juan groundwater basin. The close partnership between SBCWD and SCVWD will enable a portion this Feasibility Study to provide an additional pilot testing location for the Stanford University research efforts.

Through the research done by Dr. Reinhard and his team, several innovative technologies and methodologies will be tested and demonstrated through this Study. First, the existing corporate partnership between Stanford University and Membrane Technology and Research, Inc., a research and development firm specializing in membrane filtration technologies, will be continued to facilitate the testing of a variety of membranes. Second, the bench scale testing of multiple membranes will provide specific information on the ability of the selected membranes to effectively treat the brackish groundwater as well as information on scaling and fouling of the several membranes. Third, extensive sampling and analysis procedures will allow detection of a large number of water quality parameters as well as pharmaceuticals that are emerging as trace elements of concern.

The final stage of the proposed Stanford University pilot studies is to perform an economic and technical feasibility analysis on the pilot units. This analysis will compile relevant data, develop the potential treatment options and make recommendations. Comparisons of alternative treatment technologies will be performed using the total production cost per 1,000 gallons of water treated to the specified minimum quality standards.

SBCWD Regional Recycled Water Project

SBCWD, on behalf of the Water Resources Association of San Benito County, is pursuing the implementation of a Regional Recycled Water Project. The overall goal of the Regional Recycled Water Project is to supply recycled water to agricultural and urban customers in the Northern San Benito County area. Specific goals for this project include:

- Identify a new high quality water supply
- Protect groundwater to maintain its availability for beneficial uses
- Increase reliability of delivered agricultural irrigation water
- Provide support for ongoing improvements to the City of Hollister wastewater treatment and disposal system
- Assist the mitigation of high groundwater levels in the Northern San Benito County area

A Feasibility Study for the Project was completed in May 2005 and identified the Ultimate Regional Recycled Water Project as well as a recommendation for the first phase of recycled water deliveries. Since that time, the City of Hollister Domestic Wastewater System Improvements initiative and the Hollister Urban Water and Wastewater Master Plan identified an interim Phase 1 project that would be primarily focused on effluent disposal via continued percolation and pasture grass irrigation. The project identified in the Feasibility Study as the initial implementation of the ultimate project is currently planned to be implemented as Phase 2 of recycled water distribution in San Benito County.

Specific planning for the Phase 2 project is awaiting the recommendations from the Hollister Urban Area Water and Wastewater Master Plan and the associated Phase 1 disposal project. The initiation of any recycled water irrigation project is contingent upon the recycled water meeting quality goals that will likely require a reduction of salt mass loading to the wastewater system via the potable water. A groundwater demineralization facility would provide this reduction and allow the planning for recycled water use to continue. This specific planning stage does not have a set schedule but is intended to accomplish the following primary goals:

- Define a recommended project for implementation as the Phase 2 Recycled Water Project
- Position the project to move into design when conditions permit
- Fulfill State Water Resources Control Board requirements for positioning the project for future construction funding

City of Hollister Domestic Wastewater System Improvement Project

Following discharges of wastewater from the Hollister Domestic Wastewater Treatment Plant (DWTP) and the Hollister Industrial Wastewater Treatment Plant (IWTP), the Central Coast Regional Water Quality Control Board (RWQCB) issued a Cease and Desist Order in conjunction with an Administrative Civil Liability (ACL) Order that required a series of actions to improve the treatment and disposal process at the two wastewater treatment plants. In addition to the required improvements, the City of Hollister was prohibited from establishing new connections to the sanitary sewer collection system until the improvements are completed.

The two major requirements for the City of Hollister were to complete a Long-Term Wastewater Master Plan (LTWMP) and to implement the recommendations that were identified in the LTWMP. The LTWMP was completed in December 2005 and the recommendations are currently required to be implemented by December 2007. The City of Hollister, however, is presently reevaluating the disposal options associated with the LTWMP as part of the Hollister Urban Area Water and Wastewater Master Plan. The project is currently undergoing the final design stages in conjunction with the environmental documentation process. Ultimately, the existing pond treatment and percolation pond disposal system will be replaced with a membrane bioreactor system followed by disinfection to meet California state recycled water regulations. Disposal of the disinfected tertiary effluent will be a combination of on-site percolation and off-site irrigation.

The use of the treated effluent is contingent on the reduction of TDS, sodium and chloride concentrations in the effluent. The MOU requires that potable water supply improvements and source control be the primary means of reduction for these dissolved constituents, with demineralization of the recycled water being a last resort. Demineralization of groundwater for potable use is projected to have a large beneficial impact on the concentrations of the dissolved solids in the treated wastewater.

San Juan Bautista Water Supply Project

The City of San Juan Bautista currently has three municipal supply wells. However one well is unsealed and not usable for potable water service and one well has high nitrate concentrations and can only be used in emergency conditions. The one remaining well is not of sufficient capacity to supply the daily water needs of the City. To remedy this situation, the City has developed plans for a 0.75 million gallon per day (MGD) surface water filtration facility. The facility was planned to treat imported CVP water delivered to the City via the existing San Felipe distribution system in the San Juan Valley. The proposed treatment process would be either micro- or ultra-filtration membranes. The treated water would be supplied to the existing City distribution system. The project has been on hold since 2002 while agreements between the City and SBCWD are developed.

An alternative to this surface water treatment facility is a brackish groundwater demineralization facility. This alternative would benefit greatly from the information developed through this Feasibility Study and locating a demineralization facility to serve San Juan Bautista will be evaluated during this Study. A solution to the water supply deficiency in San Juan Bautista that would satisfy both the City and SBCWD is a preferable end-goal, regardless of the water source.

Sunnyslope County Water District Water Supply/Wastewater Treatment System Upgrades

Sunnyslope County Water District (SSCWD) provides water supply and wastewater treatment and disposal for its customers. Wastewater treatment and disposal occur via two small wastewater treatment pond systems integrated into the Ridgemark Golf Course community. The SSCWD wastewater treatment plants (WWTPs) have a relatively new Waste Discharge Requirement (WDR) permit that includes more stringent effluent quality requirements for nitrogen, TDS, chloride, sodium and other constituents. Their current pond treatment system does not provide the level of treatment needed to meet these new requirements requiring that a new treatment process will need to be implemented to address ammonia, nitrate, total suspended solids (TSS), biochemical oxygen demand (BOD), sodium, chloride and TDS. Potable water with high salinity and high hardness is the primary contributor to the high salinity wastewater, which is exacerbated by the use of residential water softeners.

The needed wastewater treatment plant improvements and the associated potable water supply improvements are very similar to the work being performed under the Hollister Domestic Wastewater System Improvement Project. SSCWD has recently begun the preliminary design phase of the project and is planning to analyze several treatment options, including connecting to the City of Hollister wastewater system, to develop a recommendation for the next step in the implementation process. The potable water supply improvement aspect of the project is on a similar schedule and is likely to be implemented regardless of the wastewater treatment alternative selected. This potable water supply improvement could be either a groundwater demineralization project or an imported water supply project.

The results of this Feasibility Study will provide valuable information to SSCWD and will assist their planning and design process for the potable water quality improvement project.

1.4 Water Supply Summary

While the overall project will provide benefits to the entire Pajaro River Watershed, the groundwater demineralization facilities are projected to be sited in the SBCWD service area and provide water to users in that area. The following two sections summarize the current water supplies and the projected future water supply needs for the northern portion of San Benito County. This information is largely gathered from and is described in more detail in the *Annual Groundwater Report for Water Year 2005*, developed by Gus Yates for SBCWD.

Water use in the SBCWD service area is divided into two main categories: agricultural and municipal/industrial (M&I). The northern portion of San Benito County is where the two major cities (Hollister and San Juan Bautista) are located and is also the home to several large and very productive agricultural areas, including the San Juan Valley and the Bolsa area. This area uses a large amount of water, both potable and non potable, and the existing supplies and future needs are being assessed through the *Hollister Urban Area Water and Wastewater Master Plan* (HUAWWMP).

1.4.1 Existing Supplies

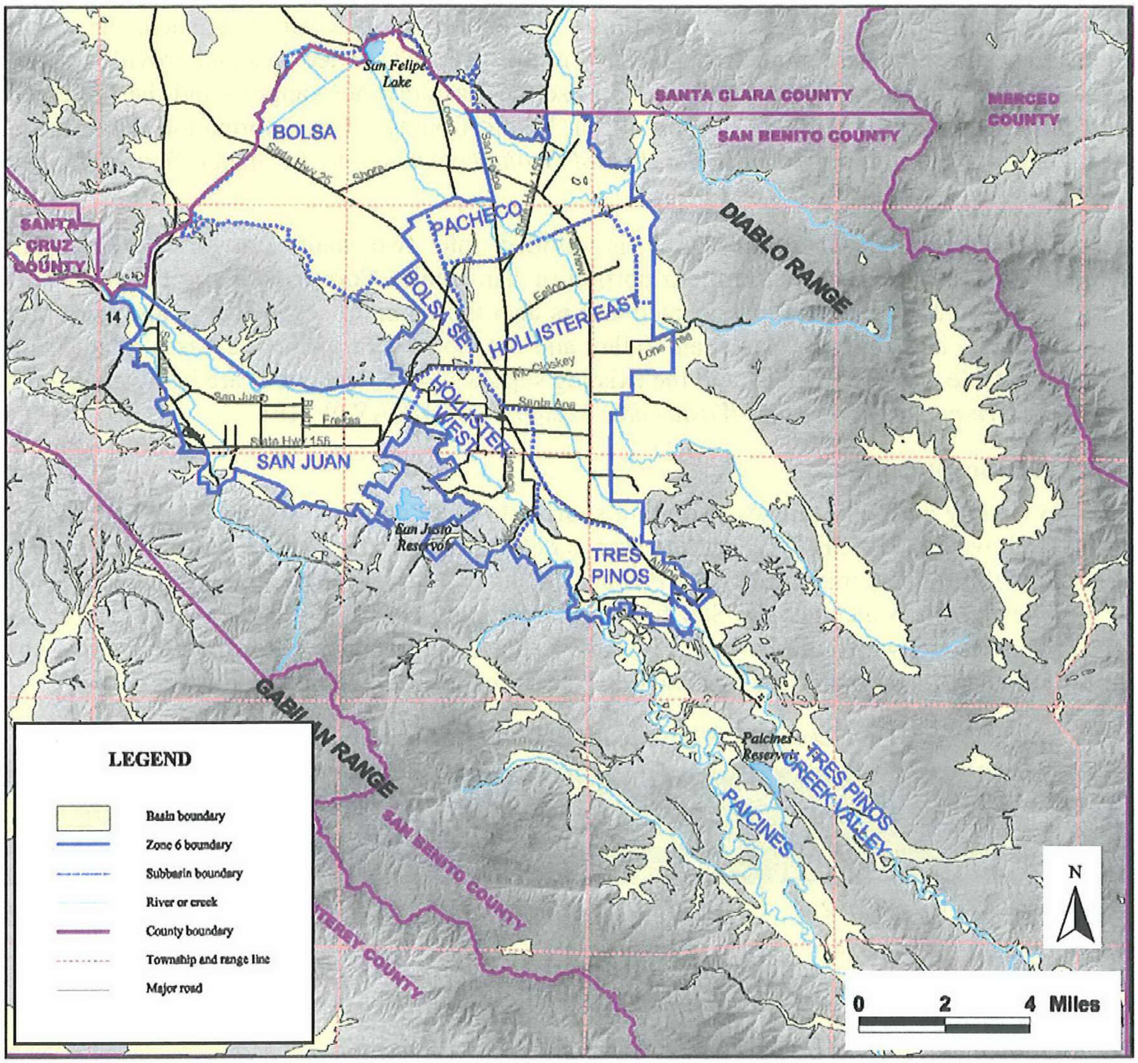
San Benito County currently utilizes two main sources to meet its water supply needs: groundwater and imported CVP water. The SBCWD service area is delineated into three zones. Of these, only lands and water users within Zone 6 may receive CVP water the other zones are limited to groundwater and surface water supplies. Zone 6 includes the San Juan, Hollister East, Hollister West, Pacheco, Bolsa Southeast and Tres Pinos groundwater sub-basins. Figure 1-4 shows the boundaries of Zone 6 and its sub-basins. Table 1-1 summarizes the water use in Zone 6 for the different water sources and types of use.

Table 1-1: Water Year 2005 Water Use in Zone 6

	Imported CVP Water Use		Groundwater Use		
Sub-basin	Agricultural	Domestic & Municipal	Agricultural	Domestic, Municipal & Industrial	Total Water Use
Pacheco	3,032	43	1,128	192	4,425
Bolsa Southeast	514	0	1,837	12	2,363
San Juan	5,841	404	5,655	953	12,853
Hollister West	651	29	1,477	3,607	5,764
Hollister East	7,295	1,902	1,248	1,339	11,784
Tres Pinos	90	553	711	1,667	3,020
Zone 6 Total	**17,454**	**2,930**	**12,056**	**7,769**	**40,209**

Source: Yates, 2005
All units in acre-feet

Figure 1-4: Location of Zone 6 and Groundwater Sub-basins



Source: Yates, 2005

In Water Year (WY) 2005 (October 2004 through September 2005), approximately 40,200 AF of water was used within Zone 6. Approximately 10,700 AF of that water (26 percent) was used for domestic, municipal and industrial use with 73 percent (7,800 AF) of that use supplied by groundwater.

A set of 18 monitoring wells are located throughout northern San Benito County. Water quality from those 18 monitoring wells has indicated that a majority of the groundwater wells have a TDS concentration exceeding 500 mg/L, the CDPH recommended limit for drinking water. Additionally, 10 of the 18 wells have groundwater quality with TDS concentrations exceeding 1,000 mg/L, the upper CDPH limit for drinking water, including all five wells located in the San Juan groundwater sub-basin. The San Juan sub-basin has historically been used as the water supply for the City of San Juan Bautista.

Groundwater in the Hollister East and West sub-basins, historically used as the M&I supply for the City of Hollister, also has high TDS concentrations. To mitigate these high TDS concentrations, SBCWD and SSCWD combined their efforts and constructed the Lessalt Surface Water Treatment Plant. In water year 2005, approximately 1,800 AF of imported CVP water was treated at this facility using microfiltration, which does not provide any salt removal. The treated water is subsequently supplied to portions of the City of Hollister and SSCWD potable water service areas. The TDS concentration of this water ranges from approximately 200 to 300 mg/L, compared to the 500 – 1,500 mg/L range found in the local groundwater. Additionally, a large number of residents and businesses in the SBCWD and SSCWD service areas have installed water softener units that remove calcium and magnesium from the water by replacing those dissolved constituents with sodium ions. The impact of water softeners on downstream processes and uses will be further discussed in Section 1.7.

Additional information and analysis of the quality of the groundwater can be found in Chapter 2.

1.4.2 Projected Future Water Supply Needs

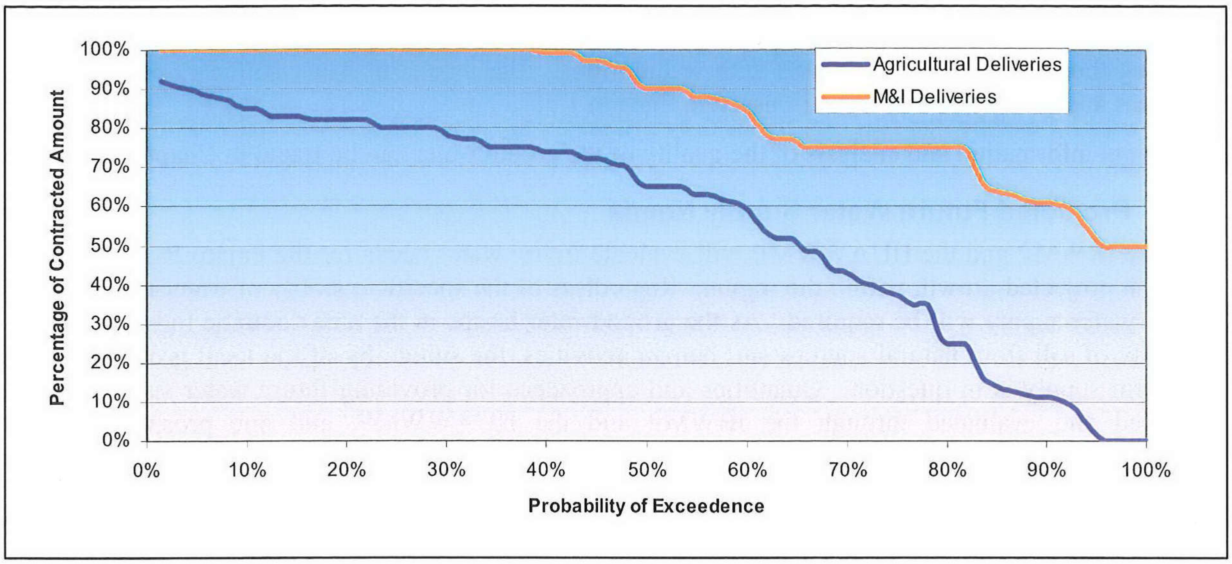
Both the IRWMP and the HUAWWMP will evaluate future water needs for the Pajaro River Watershed based on projected growth within the region. Regardless of the specific quantity of water needed, a high quality water supply will be required. As the groundwater basins in the area continue to be subjected to an influx of salt from natural sources and human activities, the suitability of the local groundwater as a long-term supply is in question. Quantities and approaches for providing future water supplies will be identified and evaluated through the IRWMP and the HUAWWMP, and one prospective supply alternative is expected to be groundwater demineralization. The results of this Feasibility Study will serve as input to the IRWMP and the HUAWWMP and will provide the necessary information to determine if groundwater demineralization is one of the water supply options to be pursued to help meet future water needs for the Pajaro River Watershed.

CVP water is another alternative for future potable water supplies. However, the reliability of these deliveries is not guaranteed. SBCWD currently has a contract entitlement for CVP water in the amount of 35,550 AFY for agricultural use and 8,250 AFY for M&I use. This contract expires in the year 2027. The CVP supply is dependent on annual hydrologic conditions, which can vary greatly from year to year. Delivery of San Felipe water, CVP water delivered through the San Luis Reservoir and the Pacheco Pumping Station, can be further reduced due to state and federal policies that allocate some portion of the available supply for environmental purposes.

The Bureau of Reclamation and the Department of Water Resources have completed computer modeling for the CVP system in an attempt to quantify the reliability of future deliveries. Based on CALSIM II model results for the 2001 Level of Development, drought year deliveries for M&I uses could be as low as 50 percent of the contract amount, while agricultural deliveries could be eliminated in up to 10 percent of the years.

Figure 1-5 is a representation of both allocations and cutbacks that can be expected over a number of years (Based on CALSIM II Model - 2001 Level of Development). The 50% probability of exceedence indicates that 50 percent of the years the CVP water allocation is expected to be greater than 65% (23,100 AFY for SBCWD) of agriculture entitlements and 90% (7,400 AFY for SBCWD) for M&I entitlements.

Figure 1-5: CVP South of Delta Delivery Probability



The long term average annual CVP allocation for agriculture (South of Delta) is estimated to be 56% (19,900 AFY for SBCWD) of the contracted entitlement. The long term average annual M&I allocation (South of Delta) is estimated to be 85% (7,000 AFY for SBCWD) of the contracted entitlement. It is important to note, however, that the method of allocation between M&I and agricultural supplies is being modified in the ongoing contract renewal process. Although the actual method of allocation is being modified, the general conditions of reduced supply availability will remain similar to those shown in Figure 1-5.

Through the development of additional groundwater supplies via demineralization, the reliance of the regional water agencies on imported water could be reduced. A reduction in imported water requirements would allow regional collaboration to develop the ability to transfer water between the regional CVP contractors to ensure that water needs can be met for all agencies on a continuous basis. The development of additional local, non drought sensitive sources provides additional water supply security for the entire region. For example, for every acre-foot of groundwater demineralized for SBCWD, a corresponding amount of CVP water could potentially be transferred to, bought by or stored with SCVWD.

1.5 Existing Water Distribution Systems

There are three existing municipal water distribution systems in the northern portion of San Benito County: the City of Hollister, the City of San Juan Bautista and the Sunnyslope County Water District systems. Additionally, there is a dedicated agricultural irrigation water supply system that distributes CVP water throughout a portion of northern San Benito County within Zone 6. This system is called the San Felipe distribution system. Through an existing intertie, the City of Hollister and SSCWD water distribution systems are linked providing the possibility for a regional project providing high quality water to both service areas.

The majority of the water supplied to the municipal systems is groundwater pumped through municipal wells that are owned, operated and maintained by Hollister, San Juan Bautista or the SSCWD. In 2005, the Lessalt surface water treatment plant provided an additional 1,777 AF of potable water to the City of Hollister and SSCWD service areas. The distribution systems for the City of Hollister and the City of San Juan Bautista will be characterized in more detail in Chapter 5. These two systems are anticipated to be the potential recipients of the demineralized groundwater that may ultimately result from the extension of this Study.

1.6 Existing Wastewater Collection and Treatment Systems

Wastewater in San Benito County is treated through a combination of private septic tanks and centralized treatment facilities. Northern San Benito County has seven wastewater treatment facilities that have significant influent flows. Of these seven treatment facilities, three serve individual developments while the other four serve larger urban and residential areas. These four main facilities are:

- City of Hollister Domestic Wastewater Treatment Plant (DWTP)
- City of Hollister Industrial Wastewater Treatment Plant (IWTP)
- City of San Juan Bautista Wastewater Treatment Plan
- Sunnyslope County Water District Ridgemark Wastewater Treatment Facility (RMK)

The Hollister Domestic and Industrial Treatment Plants and the SSCWD Ridgemark Treatment facilities utilize pond treatment and percolation pond disposal systems. The City of San Juan Bautista treatment plant utilizes a sequencing batch reactor (SBR) followed by ultraviolet disinfection for treatment prior to discharge to San Juan Creek, which ultimately discharges to the San Benito and Pajaro Rivers. In WY 2005, these four facilities treated and disposed of approximately 4,200 AF of wastewater. Of this total, approximately 2,550 AF was percolated into the San Juan sub-basin. This source of groundwater recharge contributes approximately 1,635 tons of additional salt (above that found in the M&I potable water supply) to the San Juan sub-basin.

1.7 Water Supply Impacts on Recycled Water Use

The water supply and wastewater collection/treatment systems are closely linked, especially in terms of water quality and salinity. The TDS in the potable water supply provides a base load of salinity to the wastewater collection/treatment system. Additionally, for locations such as Hollister where the potable water has high hardness, many residents and businesses have employed the use of water softener units. These water softener units remove calcium and magnesium from the potable water through an exchange process that incorporates a media saturated with sodium and chloride. While passing through the media, the calcium and magnesium ions in the water are replaced with sodium and chloride ions. To maintain the ability of the water softener unit to remove hardness, the sodium and chloride must be regenerated periodically. This is accomplished by flushing the system with brine containing high concentrations of sodium and chloride. The flushing process discharges the waste brine to the sanitary sewer system. This causes an increase in concentration of sodium, chloride and total dissolved solids in the influent to the wastewater treatment facility.

Primary and secondary treatment processes are not equipped to remove dissolved solids from the wastewater and the use of treatment ponds may result in increased concentrations of dissolved solids as evaporation removes water while leaving the dissolved solids behind. The high concentrations are then passed through to the treated effluent, limiting the potential use of treated wastewater as recycled water, especially for salt sensitive plants such as lettuce and strawberries. There are three main alternatives for mitigating the dissolved solids concentrations in the recycled water:

1) Blending with high quality water
2) Advanced treatment of recycled water
3) Reduction in salinity of the potable water supply through either:
    - Demineralization or;
    - Use of a higher quality supply.

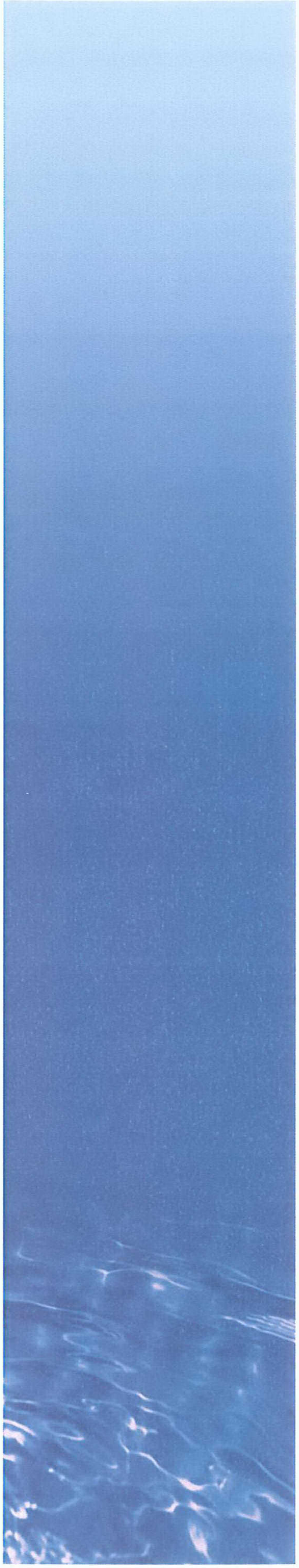
Blending with high quality water in the San Benito area would require importing additional CVP water. The San Juan sub-basin is experiencing localized areas of high groundwater, so importing additional CVP water and reducing groundwater pumping would only exacerbate this problem. Additionally, this blending supply has limited reliability in dry years. This option also does not address the increase in salt loading to the basin that occurs through the use of imported water.

Advanced treatment of the recycled water is a second method to reduce salinity in the recycled water; however, this could require several stages of advanced treatment processes potentially including membrane filtration and reverse osmosis. As part of the City of Hollister Domestic Wastewater Treatment Improvement Project, a membrane bioreactor (MBR) system is planned to be implemented. This treatment process produces very high quality effluent but will not provide any TDS or salinity removal from the wastewater. To meet the TDS goals for use of recycled water as an irrigation supply, reverse osmosis would be required as an additional treatment step prior to distribution. This alternative would only provide benefits to the recycled water customers and would not provide any means to meet the water quality goals set for potable water.

The third option, an improvement in the potable water supply would provide similar benefits to the wastewater salinity levels as both of the first two options. In addition to the reduction of dissolved solids in the treated wastewater, reducing dissolved solids concentrations in the potable water supply would provide benefits to potable water users. The higher quality potable water can increase the life expectancy of household appliances and can reduce the annual maintenance needed for these appliances as compared to a water supply higher in TDS and hardness. These benefits can be realized through either increased use of CVP supply for M&I uses or through demineralization of the groundwater supply.

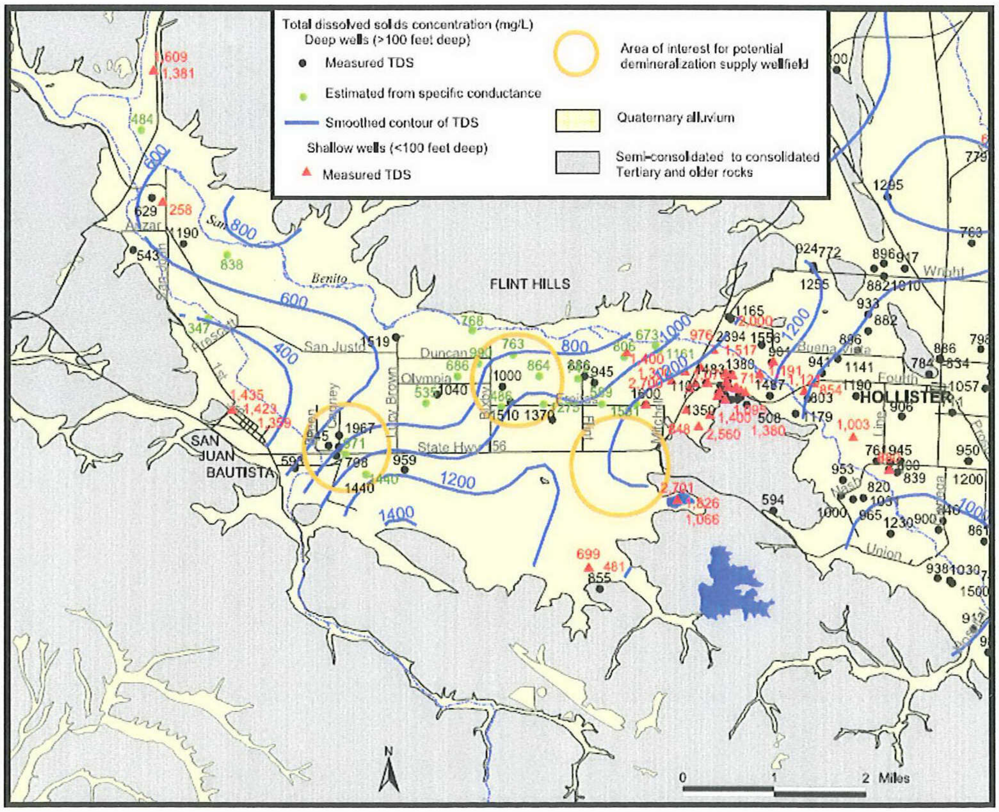
Ultimately, the benefits of either the second or third alternative are contingent on the export of salts from the groundwater basin. Export of the waste salts through liquid disposal or solid waste landfilling is critical to a long-term salt management solution for the Pajaro River Watershed.

For the City of Hollister and SBCWD to meet the goals of producing treated wastewater with suitable TDS, sodium and chloride concentrations for widespread recycled water use, potable water quality improvements appear to be a cost-effective and beneficial approach. This approach is also identified in the HUAWWMP MOU as the principal means of reducing concentrations of dissolved solids in recycled water. The Pajaro River Watershed Groundwater Desalination Feasibility Study will investigate the technical feasibility, political acceptance and financial aspects of this option to provide benefits to the Pajaro River Watershed.



Chapter Two

Source Water Evaluation



Total dissolved solids concentration (mg/L)
Deep wells (>100 feet deep)
● Measured TDS
● Estimated from specific conductance
Smoothed contour of TDS
Shallow wells (<100 feet deep)
▲ Measured TDS
Area of interest for potential demineralization supply wellfield
Quaternary alluvium
Semi-consolidated to consolidated Tertiary and older rocks
FLINT HILLS
SAN JUAN BAUTISTA
HOLLISTER
San Justo
Duncan
Olympia
State Hwy 156
Buena Vista
Fourth
Union
Wright
Benito
600
800
400
1000
1200
1400
N
0
1
2 Miles

Chapter 2 Source Water Evaluation

2.1 Groundwater Basin Characteristics

The Pajaro River Watershed Groundwater Desalination Feasibility Study is focused on evaluating the potential for development of a potable water supply from high TDS groundwater in the San Juan Valley portion of San Benito County. The San Juan Valley is underlain by part of the Gilroy-Hollister groundwater basin, which covers most of northern San Benito County. The San Juan sub-basin is separated from other parts of the basin by faults and folding in the hills on the north side of the valley (Lomerias Muertas and Flint Hills) and by a constriction in alluvial width at the east end of the valley. The southern edge of the sub-basin is defined by the San Andreas Fault, which is relatively impermeable to groundwater flow. The basin consists of many thin, discontinuous layers of sand, silt, clay and gravel. This layering tends to impede the vertical flow of water within the basin, such that water levels and water quality in aquifers at shallow depth can be substantially different from water levels and quality in deeper aquifers. Most water supply wells draw primarily from aquifers 150 to 500 feet below the ground surface, which in this analysis are considered "deep" aquifers[2]. Because recharge occurs at the top of the aquifer system while pumping is largely from deep aquifers, there is a downward vertical hydraulic gradient in most locations. This means that shallow groundwater, typically of poor quality, will eventually percolate downward and affect deep aquifers. These changes are expected to occur over long periods of time as historical analysis has shown a very slow change in deep groundwater quality over time. The slow decline in quality also suggests that recovery would be slow for water already showing degradation.

The San Juan sub-basin is mainly composed of Holocene (less than 10,000 years old) and Late Pleistocene (between 10,000 and 125,000 years old) alluvial deposits with high permeability relative to other deposits in the region. Below these surface deposits lie the Purisima Formation, which has an estimated age of 3 to 6 million years and is comprised of sand, silt and gravel. This is the main water bearing formation in the region. The formation extends below the entire San Juan Valley as well as under the surrounding hills. Deep wells in the San Juan Valley typically draw water from the Purisima formation (more than 100 feet below the ground surface) and it is estimated that there is substantial depth of the formation below even the deepest wells.

Groundwater in the San Juan Valley has historically been used primarily as a source for agricultural irrigation. However, it also supplies many private potable water wells and a small number of municipal wells. A small percentage of the wells in the San Juan Valley are less than 150 feet deep and a majority of the wells pump from 150 to 500 feet below the ground surface. Groundwater quality is generally better in deep aquifers, but still poor. The concentration of total dissolved solids (TDS) is a general indicator of overall water quality and in most wells ranges from 600 to 1,200 mg/l, exceeding the secondary drinking water standard of 500 mg/L. Shallow groundwater TDS is generally higher, averaging 2,300 mg/L.

A well near the City of Hollister Domestic Wastewater Treatment Plant (DWTP) was selected for a pilot test of demineralization performance. The quality of the source water can affect the demineralization process, so a sample from the test well was collected on March 28, 2006. The laboratory analysis results are summarized in Table 2-1. Additional parameters were analyzed but were below their respective detection limits. These additional constituents include hydroxide, carbonate, anionic surfactants, odor, aluminum, arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver and zinc.

---

[2] Shallow is considered to be less than 50 feet below ground surface (bgs), intermediate depth is 50 – 150 feet bgs and deep is 150 – 500 feet bgs.

Table 2-1: San Juan Sub-Basin Pilot Testing Water Quality Analysis

Parameter	Concentration	Parameter	Concentration
Total Hardness (as $CaCO_3$)	650 mg/L	Fluoride	0.33 mg/L
Calcium	88 mg/L	pH	6.90
Magnesium	110 mg/L	Specific Conductance	2,400 μmhos/cm
Sodium	350 mg/L	Total Dissolved Solids	1,540 mg/L
Potassium	5.7 mg/L	Apparent Color	10 units
Total Alkalinity (as $CaCO_3$)	640 mg/L	Turbidity	3.1 NTU
Bicarbonate	640 mg/L	Iron	610 μg/L
Sulfate	240 mg/L	Manganese	43 μg/L
Chloride	330 mg/L	Nickel	23 μg/L
Nitrate	6 mg/L	Silica	31 mg/L

The test results indicate the well has relatively high levels of many dissolved constituents, including TDS, hardness, sodium and chloride. These constituents are often the main target of potable water demineralization processes as they can have negative impacts on taste and can increase the potential for scaling in household water appliances. Meanwhile, higher than expected concentrations of coliform bacteria in the groundwater sample indicated a high potential for wastewater influence on this groundwater well. The presence of these constituents cast doubt on the representative nature of the other water quality parameters measured at this well. Such a well would not be considered for potable water supply due to the coliform activity and associated unacceptable health risks in the event of reliability problems at the demineralization facility. Due to these water quality concerns, the City plans to destroy the well shortly after the completion of the reverse osmosis pilot testing program.

A second well located farther from the DWTP was selected for additional testing. Its water quality is summarized in Table 2-2 and is considered more representative of water with potential use as demineralized groundwater from the San Juan Valley.

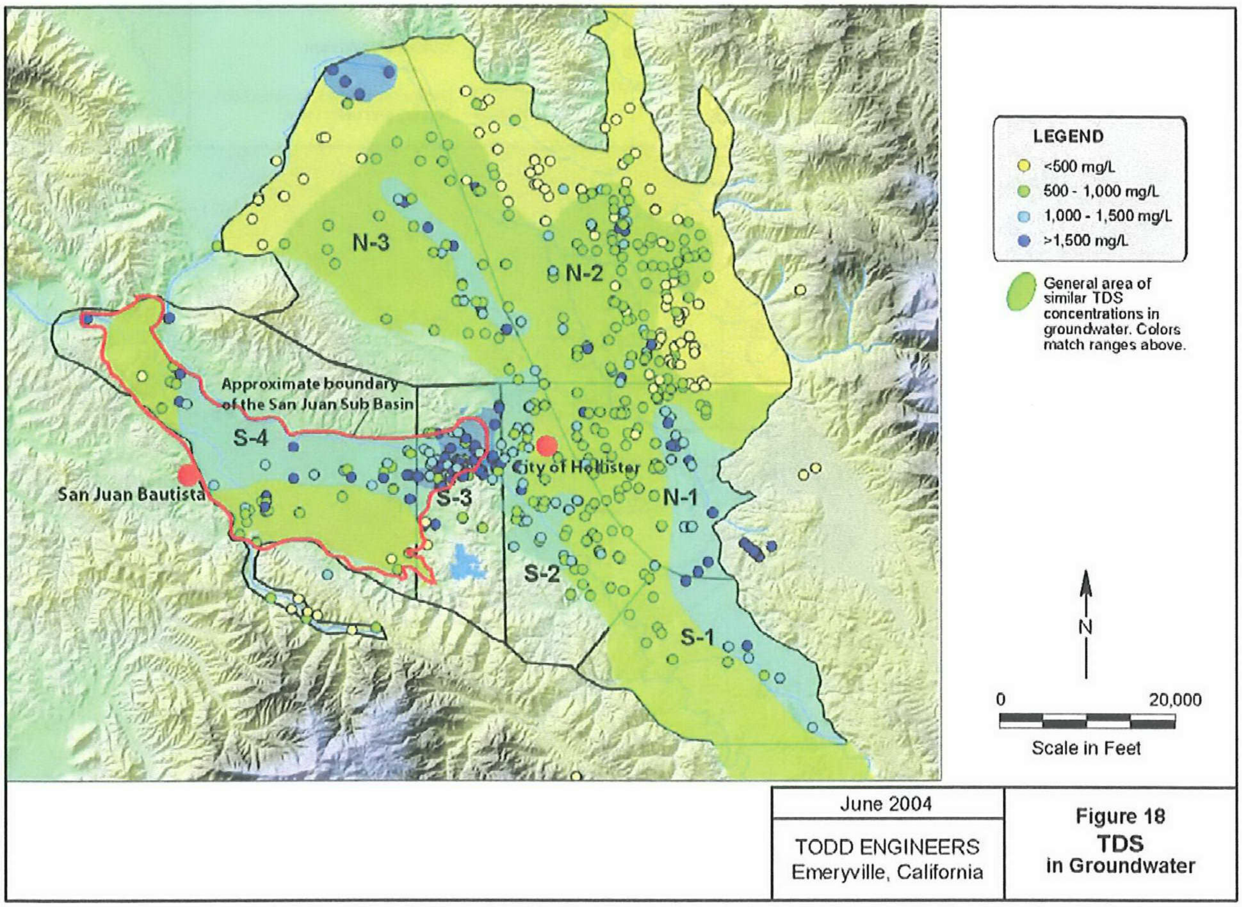
Table 2-2: Central San Juan Sub-Basin Water Quality Analysis

Parameter	Concentration	Parameter	Concentration
Total Hardness (as $CaCO_3$)	1,100 mg/L	Fluoride	0.55 mg/L
Calcium	120 mg/L	pH	7.2
Magnesium	190 mg/L	Specific Conductance	2,670 μmhos/cm
Sodium	240 mg/L	Total Dissolved Solids	1,870 mg/L
Potassium	2.2 mg/L	Apparent Color	10 units
Total Alkalinity (as $CaCO_3$)	520 mg/L	Turbidity	6.9 NTU
Bicarbonate	520 mg/L	Iron	< 100 μg/L
Sulfate	540 mg/L	Manganese	1,800 μg/L
Chloride	220 mg/L	Nickel	28 μg/L
Nitrate	210 mg/L	Silica	29 mg/L

Regional mapping of groundwater quality was completed by Todd Engineers (2004) in a report entitled *Development of a Water Quality Monitoring Program for the Hollister Groundwater Basi*n. This report identified spatial variations of multiple constituents found in the Gilroy-Hollister Groundwater Basin. The pattern for TDS identified in the 2004 report is shown in Figure 2-1. The data are for wells of all depths. In most areas the wells are water supply wells representative of relatively deep aquifers. At the

DWTP, IWTP and nearby Whittaker and McCormick/Teledyne groundwater contamination sites (labeled area S-3 in the figure), the data include numerous shallow monitoring wells.

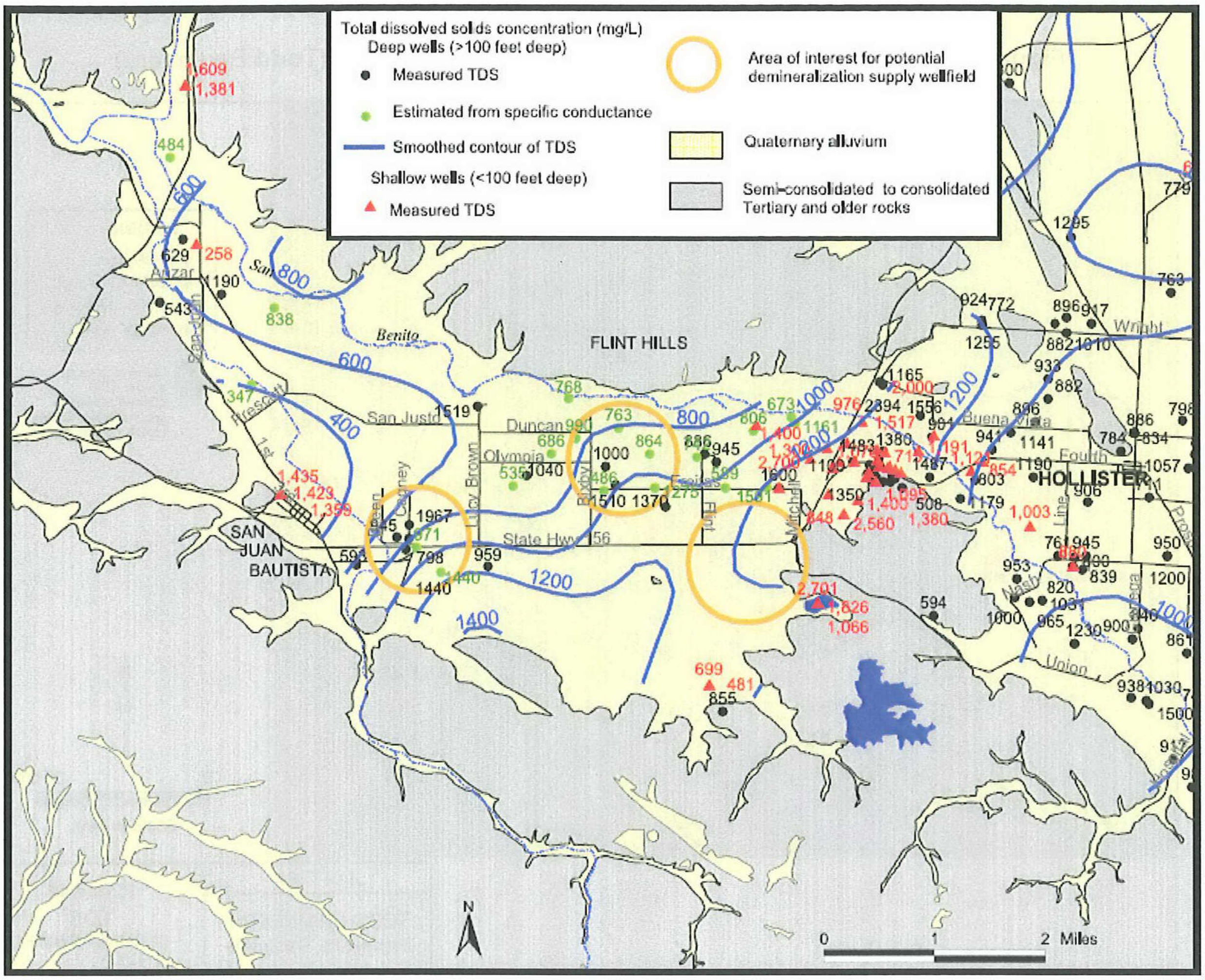
Figure 2-1: Hollister Area Groundwater TDS Concentrations (Todd Engineers)



Data from the Todd Engineers study was supplemented with measurements of specific conductance to obtain a more complete picture of TDS variation in the San Juan Valley. Specific conductance (or electrical conductivity) is more commonly measured than TDS, and the two parameters are linearly correlated. Figure 2-2 shows contours of TDS concentration in deep and shallow wells in the San Juan Valley and point measurements for shallow and deep wells for the Hollister groundwater basin and the San Juan Valley area, respectively. The point measurements show high spatial variability, and the contours are smoothed to honor most but not all data points.

The TDS map reveals that concentrations are generally higher near the southern and eastern boundaries of the sub-basin. Concentrations are generally low along the San Benito River and near the northwest end of the sub-basin. The low-TDS zone along the river almost certainly results from local percolation of surface water, and the regional southeast to northwest TDS gradient probably stems from the depositional environment in which various units of the Purisima Formation were formed (marine versus non-marine). The TDS contours were used to develop the existing conditions for the groundwater model analysis summarized in later sections.

Figure 2-2: San Juan Valley Groundwater TDS Concentrations (Gus Yates, 2006)


Total dissolved solids concentration (mg/L)
Deep wells (>100 feet deep)
● Measured TDS
● Estimated from specific conductance
Smoothed contour of TDS
Shallow wells (<100 feet deep)
▲ Measured TDS
Area of interest for potential demineralization supply wellfield
Quaternary alluvium
Semi-consolidated to consolidated Tertiary and older rocks
FLINT HILLS
SAN JUAN BAUTISTA
HOLLISTER
Benito
San Justo
Duncan
Olympia
State Hwy 156
Buena Vista
Fourth
Wright
Union
Nash
Alzar
Lucy Brown
Bixby
Fairview
Flint
Mitchell
Line
1st
600
800
400
1000
1200
1400
N
0
1
2 Miles

In conclusion, the groundwater quality mapping shown in Figure 2-2 indicates that much of the groundwater in the San Juan sub-basin has TDS concentrations in excess of State of California secondary standards and is currently unsuitable for a consistent potable public water supply. TDS concentrations commonly exceed 1,000 mg/L, making much of the San Juan sub-basin groundwater suitable as a source supply for a groundwater demineralization treatment process.

2.2 CDPH Source Water Assessment Requirements

Prior to the implementation of any new potable water supply project, there are several important steps that must be completed to ensure the protection of public health. These steps are defined by the California Department of Public Health (CDPH) and are summarized in the following sections.

2.2.1 California Drinking Water Source Assessment and Protection Program

CDPH administers the Drinking Water Source Assessment and Protection (DWSAP) Program. The Assessment is the main part of the overall drinking water source protection program. The Assessment includes three primary items:

1) A delineation of the area around a drinking water source from which contaminants might reach that drinking water supply;

2) An inventory of possible contaminating activities (PCAs) that might lead to the release of microbiological or chemical contaminants within the delineated area; and
3) A determination of the PCAs to which the drinking water source is most vulnerable.

The information is compiled into a report that includes a map, calculations, checklists and a summary of the findings.

An assessment must be completed for every drinking water source in the state. Technically, CDPH is required to conduct the assessments for the existing water supplies, but for various reasons many water suppliers have conducted their own assessments which are submitted to CDPH for review. Nearly all of the 16,000+ drinking water sources have already been assessed under this program. When considering a new drinking water source, it is prudent to obtain information from CDPH about existing assessments done for water sources in the same vicinity, particularly those drawing from the same watershed or aquifer system. Assessments for new water supplies are typically completed during the permitting process based on a report prepared by the public water supplier.

The assessment must be done in a specific manner, in compliance with detailed guidance documents available from CDPH, including the necessary forms and checklists. Relevant DWSAP forms are included as Appendix A. The major required elements are summarized below:

1) Location of the Drinking Water Source – Document the location (latitude, longitude) of the intake or well by a global positioning system (GPS) with accuracy of 25 meters, or by another method with equivalent accuracy. An interim location may be obtained through use of a United States Geologic Survey (USGS) quadrangle map (7.5 minute series) or another method with similar accuracy.
2) Delineation of Source Area and Protection Zones – Identify recharge area boundaries (if known) and indicate on the map. Zones are required which indicate areas of influence for microbiological contaminants (shortest travel time) and chemical contaminants (longer travel times). These zones may be determined by assuming a fixed radius around the well for each zone, or a modified method if the direction of flow of the groundwater is known, taking into account the type of aquifer material (e.g. fractured rock vs. sand).
3) Drinking Water Physical Barrier Effectiveness Checklist – Evaluate the effectiveness of any physical barriers (hydrologic features) in preventing contaminants from reaching the source (low, moderate or high).
4) Inventory of Possible Contaminating Activities (PCAs) – Identify the types of PCAs in each of the protection zones.
5) Vulnerability Ranking – Evaluate each PCA in terms of its risk ranking, location (zone) and the Physical Barrier Effectiveness of the source. Prioritize PCAs to identify those to which the source is most vulnerable.
6) Assessment Map – Prepare an assessment map (based on USGS quadrangle map, 7.5 minute series) that shows the location of the drinking water source, the source area (zones plus recharge area), the Protection Zones and the prioritized listing of PCAs with the area or zone(s) in which they occur. This map will assist in determining which PCA poses the greatest threat.
7) Summary Report – Complete the assessment, prepare a summary and submit to CDPH. The completed assessment should include the assessment map, delineation calculations, physical barrier effectiveness checklists, PCA inventory forms and vulnerability ranking.
8) Public Notification – Specific information regarding the assessment must be included in the water system's annual consumer confidence report.

Once complete, the information must be entered into the TurboSWAP program, which is a software package that allows users to input the data in a consistent format, as well as allows CDPH to analyze results and create reports.

2.2.2 Characterization of the Water Source

For regulatory purposes, all drinking water sources are considered either groundwater or surface water. The surface water category includes groundwater which is "under the direct influence of surface water." This distinction is important, since additional treatment requirements apply for surface water supplies beyond those required of groundwater supplies. Collectively, these are known as the Surface Water Treatment Rule and generally require filtration and disinfection of the water before distribution. All other drinking water standards for microbiological and chemical parameters are the same for surface water and groundwater; however the required monitoring frequencies are generally greater for surface water supplies because of their increased susceptibility to contamination. Also, the level of certification required to operate a surface water system is typically higher than required for a groundwater system[3].

There is a subtle but important distinction between groundwater and surface water in terms of the assessment of the source water. If the source is surface water, then it is the responsibility of the water supplier to conduct a sanitary survey, which must be updated every five years. A sanitary survey is a more detailed analysis than a source water assessment. Consequently, a properly conducted sanitary survey will meet the requirements of a source water assessment, but not vice versa.

CDPH uses a multi-step program for determining if a groundwater source is "under the direct influence of surface water" and thus subject to the surface water treatment rules. If a source is clearly groundwater based on existing records, then no further review is needed. Therefore, the first step is a "screening" process to identify whether the source is obviously groundwater, thereby eliminating the need for more detailed analysis. Assuming the source is not obviously surface water (lake, river, etc.) the following steps are included in the CDPH approach:

- Review of system records.
- Assessment of the well to determine if it is clearly groundwater or if further analysis is needed.
- Complete review of the systems files followed by a field survey. Pertinent data is gathered such as source design and construction, evidence of direct surface water contamination, water quality analyses, indicators of waterborne disease outbreaks, operational data such as pumping rates, customer complaints regarding water quality or water related infectious illness.
- Conducting particulate analysis and other water quality sampling and analyses.

Wells with perforations or a well screen less than 50 feet in depth are considered "shallow" and will require further evaluation under the DWSAP. For deeper wells, a review of construction records (e.g. well logs) can be undertaken in lieu of specialized water quality monitoring. If the records indicate that there is an adequate sanitary seal (generally concrete or clay to a depth of at least 50 feet), or that the casing penetrates a confining bed, or that the casing is only perforated below a confining bed, then the source may be considered groundwater. Other recommended criteria include the well being located at least 200 feet from any surface water, and that the water quality records indicate no detection of coliform bacteria over the past three years and no history of turbidity problems. For any new wells, as are planned for any implementation of this project, conforming to the existing well construction standards would result in a high likelihood that the water source would be considered groundwater.

If the well is not clearly groundwater, then specialized testing must be conducted. Two types of testing are required: discrete samples for bio-indicators of surface water influence, and time-based water quality characteristics.

Discrete samples are collected and analyzed for the presence of particulate matter known to be associated with surface water. This is known as Microscopic Particulate Analysis (MPA) and is generally an examination under a microscope for the presence of different indicators of surface water: diatoms, rotifers, coccidia, insect parts, Giardia and Cryptosporidium. Approximately 1,000 gallons of water must be filtered over approximately one day, and the material on the filter is examined under a microscope. Depending on the number of each indicator found, a specific ranking formula is used to determine the likelihood of surface water influence. Discrete samples are generally collected from the water source during periods when the source is most vulnerable, generally during heavy rain events. At least two such sampling events must be conducted.

---

[3] The implementation of any project to be recommended by this Feasibility Study is planned to only consider water classified as "groundwater" by CDPH. The additional discussion of the distinction between groundwater and surface water is included to illustrate the benefits of a "groundwater" source.

The other type of required sampling to determine whether a source is under the influence of surface water is time-based sampling for parameters that may vary along with the nearby surface water. Significant and relatively rapid shifts in characteristics such as temperature, pH, conductivity or turbidity that closely correlate with climatological or surface water conditions indicate that the source is influence by surface water. Generally, daily sampling is conducted from both the well and a nearby surface water supply to provide a basis for this analysis.

Finally, regardless of whether the source water is groundwater or surface water, a complete Title 22 analysis must be completed. The presence of any parameters above the primary or secondary standards will trigger more-frequent monitoring requirements and additional requirements in the operating permit.

2.3 Wellfield Siting Criteria

The groundwater supply wells for the demineralization treatment process are a key element of the overall demineralization system. The location and specifications for these wells will impact the water quality supplied to the treatment process which ultimately impacts the required treatment equipment and the facility operation. In identifying potential locations for the supply wells, the following criteria were used.

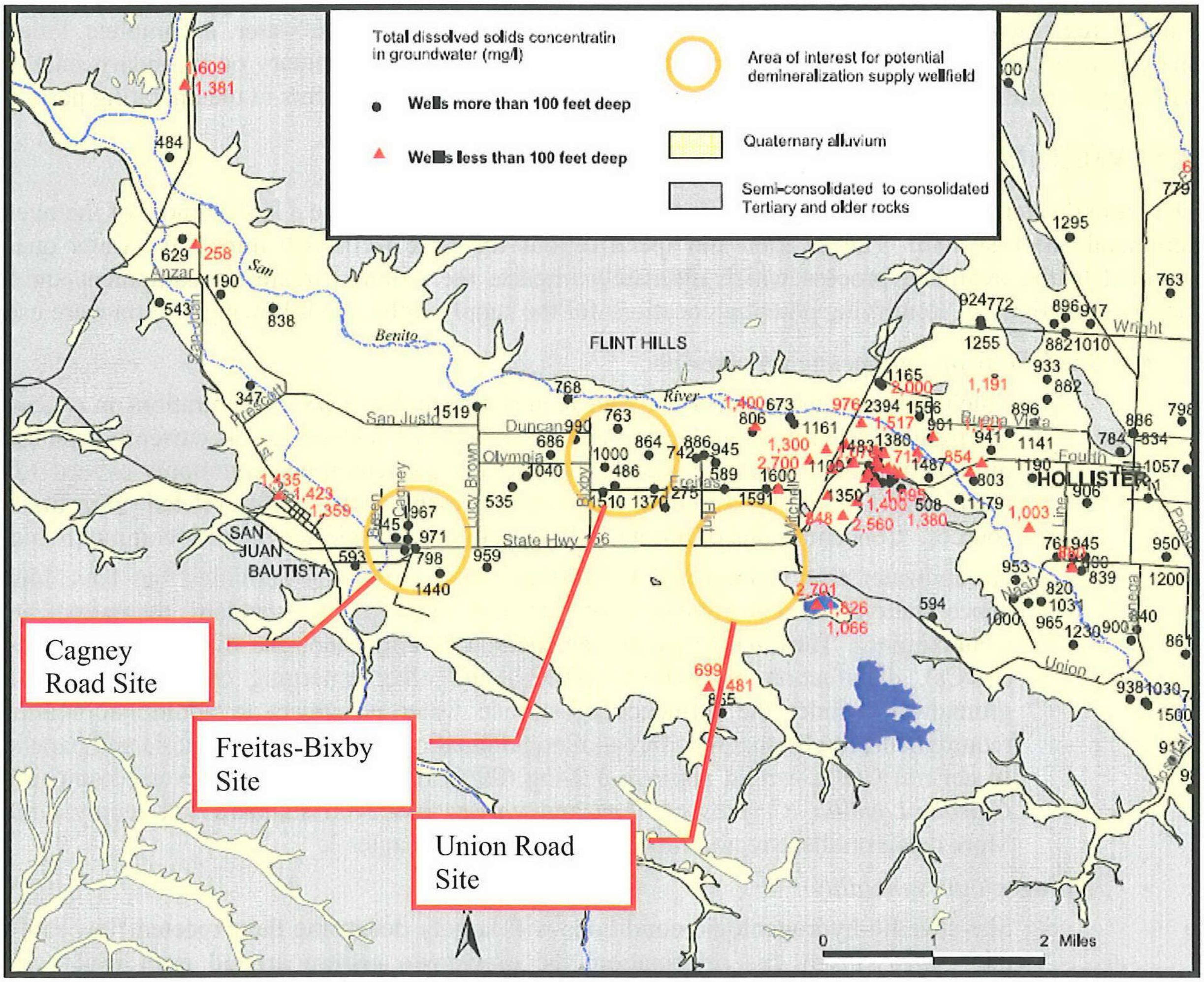
- *Availability of appropriate groundwater*
    - Much of the groundwater in the San Juan sub-basin has TDS concentrations in excess of Environmental Protection Agency (EPA) secondary standards and is currently unsuitable directly as a potable public water supply. TDS concentrations commonly exceed 1,000 mg/L, which is the threshold of eligibility for many water-quality related grant funding sources. Concentrations of nitrate, sulfate, sodium and chloride are also commonly high.
    - Groundwater that is impacted by surface water or human activities can have higher concentrations of constituents that are not removed by standard demineralization technologies. These constituents can include certain endocrine disrupting compounds (EDCs), disinfection by-products (DBPs) and other emerging contaminants. Also, groundwater under the influence of surface water is subject to additional treatment requirements to eliminate the threat of contamination from specific bacteria and parasites. In general CDPH would approve a 2-log (99%) removal credit for reverse osmosis for *Giardia Lamblia*, *Cryptosporidium* and viruses based on standard salt removal rates. More detail on these requirements is presented in Chapter 3.
- *Hydrogeologic suitability*
    - Site-specific hydrogeologic conditions will largely determine the expected flow rate for the wells. From this information, the drawdown pattern around each well can be estimated, along with the minimum spacing required between adjacent wells.
    - Well depth is another consideration for site suitability. Where shallow groundwater quality differs from deep groundwater quality, as is usually the case in the San Juan sub-basin, then different water quality objectives and demineralization supply criteria may be met by tailoring well depth accordingly.
- *Proximity to potential potable uses*

- The major potable water demands in northern San Benito County are in and around the Cities of Hollister and San Juan Bautista. There are additional potable demands at rural residences in agricultural areas. However, these rural residential uses are small and dispersed and would be expensive to serve from a centralized demineralization facility. Siting the wellfield near the end users will reduce the required length of pipeline and hence the overall cost of the demineralization project.

2.4 Initial Screening of Potential Wellfield Locations

Three general locations in the San Juan Valley were initially selected as potential sites for groundwater extraction wells. The three sites were chosen based on the criteria specified in the previous section. Their locations are shown in Figure 2-3.

Figure 2-3: Potential Well Site Locations


Total dissolved solids concentratin in groundwater (mg/l)
Wells more than 100 feet deep
Wells less than 100 feet deep
Area of interest for potential demineralization supply wellfield
Quaternary alluvium
Semi-consolidated to consolidated Tertiary and older rocks
FLINT HILLS
SAN JUAN BAUTISTA
HOLLISTER
San Benito River
Cagney Road Site
Freitas-Bixby Site
Union Road Site
0
1
2 Miles

For this discussion, the three sites are identified by nearby major roadways: the "Cagney Road site" (west), "Freitas-Bixby site" (middle), and the "Union Road site" (east). Table 2-3 summarizes key characteristics of each site.

Table 2-3: Potential Well Site Summary

Criteria	Union Road Site	Freitas-Bixby Site	Cagney Road Site
General TDS Concentrations (mg/L)	NA	800 – 1300	800 - 1400
Nearby surface water sources	McCormick/Teledyne Pond	San Benito River	San Juan Creek
General Unit Specific Capacity of wells (gpm/ft/ft)[1]	NA	0.5	0.1
Basin hydraulic conductivity[2] (feet/day)	1 – 100	100	100
Nearby RWQCB regulated sites [3]	McCormick/Teledyne, Whittaker, San Juan Oaks Golf Course	Hollister Domestic Wastewater Treatment Plant	San Juan Bautista Wastewater Treatment Plant
Relationship to Areas of High Pumping	Few nearby wells	Multiple small wells in area, linear wellfield could mitigate proximity impacts, if any	Several large wells in area, moving supply wells to north could mitigate proximity impacts, if any

NA – Not available

Notes:

1 – Gpm/ft/ft = gallons per minute per foot of drawdown per foot of perforated interval

2 – Results from calibrated groundwater model

3 – See Section 2.4.3

2.4.1 Well Specific Capacity

Groundwater well production capacity is largely dependent on the aquifer transmissivity, which is a measure of the ease with which groundwater moves through the aquifer material. In general, a higher transmissivity will allow a specific well to produce more water with less drawdown. Several surrogate indicators of transmissivity include well yield (gallons per minute, gpm) and unit specific capacity (gallons per minute per foot of drawdown per foot of screened interval, gpm/ft/ft). Well yield is the most commonly measured of these two parameters and is related to transmissivity, screen length, well diameter and pump horsepower. Other factors being equal, a longer well screen will increase yield and/or decrease drawdown. Unit specific capacity is the well yield divided by the drawdown divided by the length of the screened interval. Unit specific capacity is a more accurate indicator of aquifer transmissivity because it accounts for the screen length and drawdown in the well when the discharge measurement is made. However, fewer data points are available for this parameter.

Well yields in the San Juan Valley are documented through two sources:

- SBCWD measurements of large irrigation wells for billing purposes
- Values reported on well completion reports and drillers' logs.

Values reported by drillers are often crudely estimated and incentives to overestimate the yield may further reduce the accuracy of the values. Figure 2-4 shows the available records of well yields, color-coded by source. The wide spatial variability and the small number of points make generalization of basin-wide spatial patterns difficult. In general, wells near the Freitas-Bixby site appear to have lower average yields than wells near the Cagney Road study site. The Union Road site has minimal documented yield data; however, anecdotal reports indicate that poor yields resulted in few installed wells in the area. In contrast to these observations, personnel at San Juan Oaks golf course have reported high yields for their wells as well as neighboring wells.

Figure 2-4: San Juan Valley Well Yields

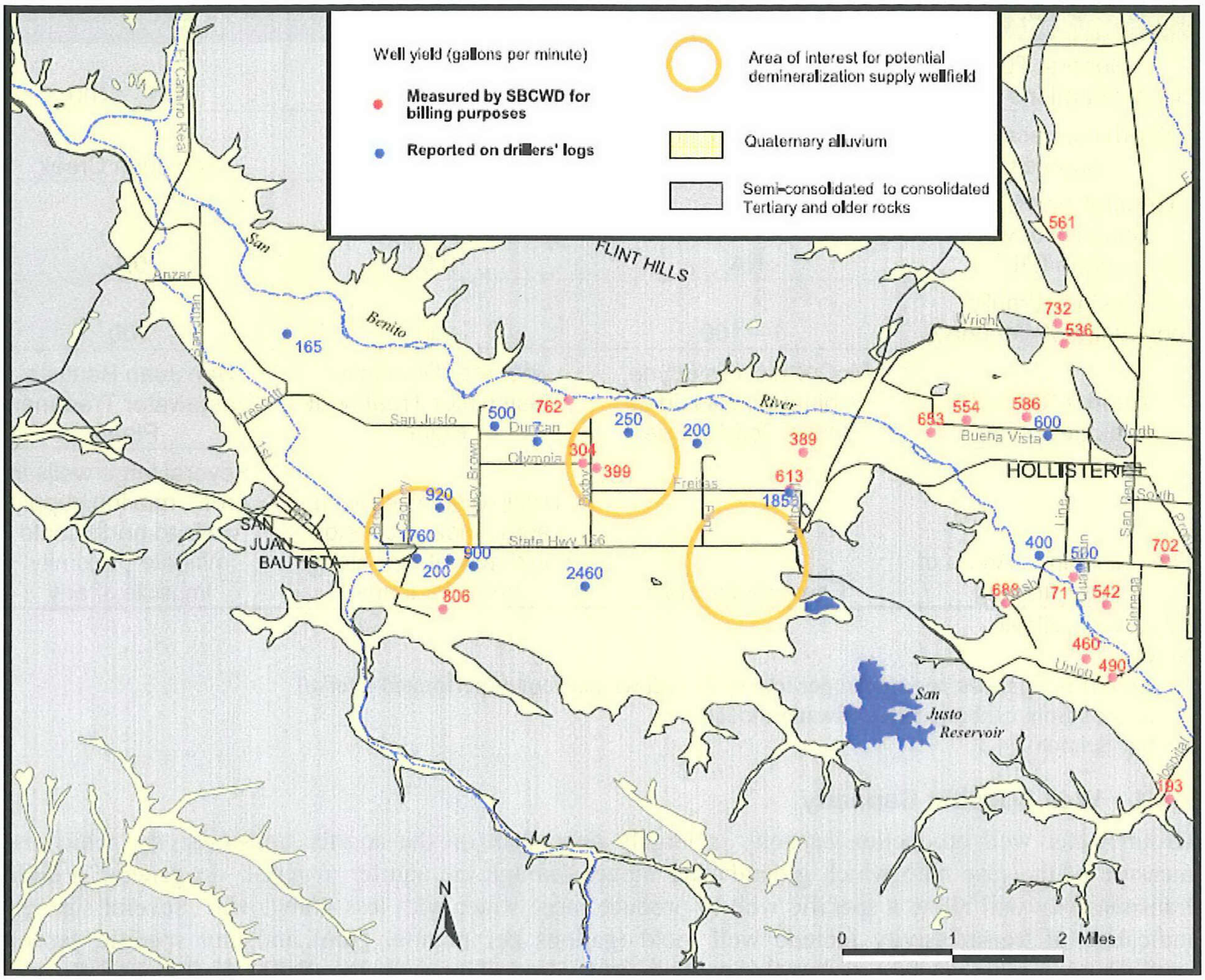
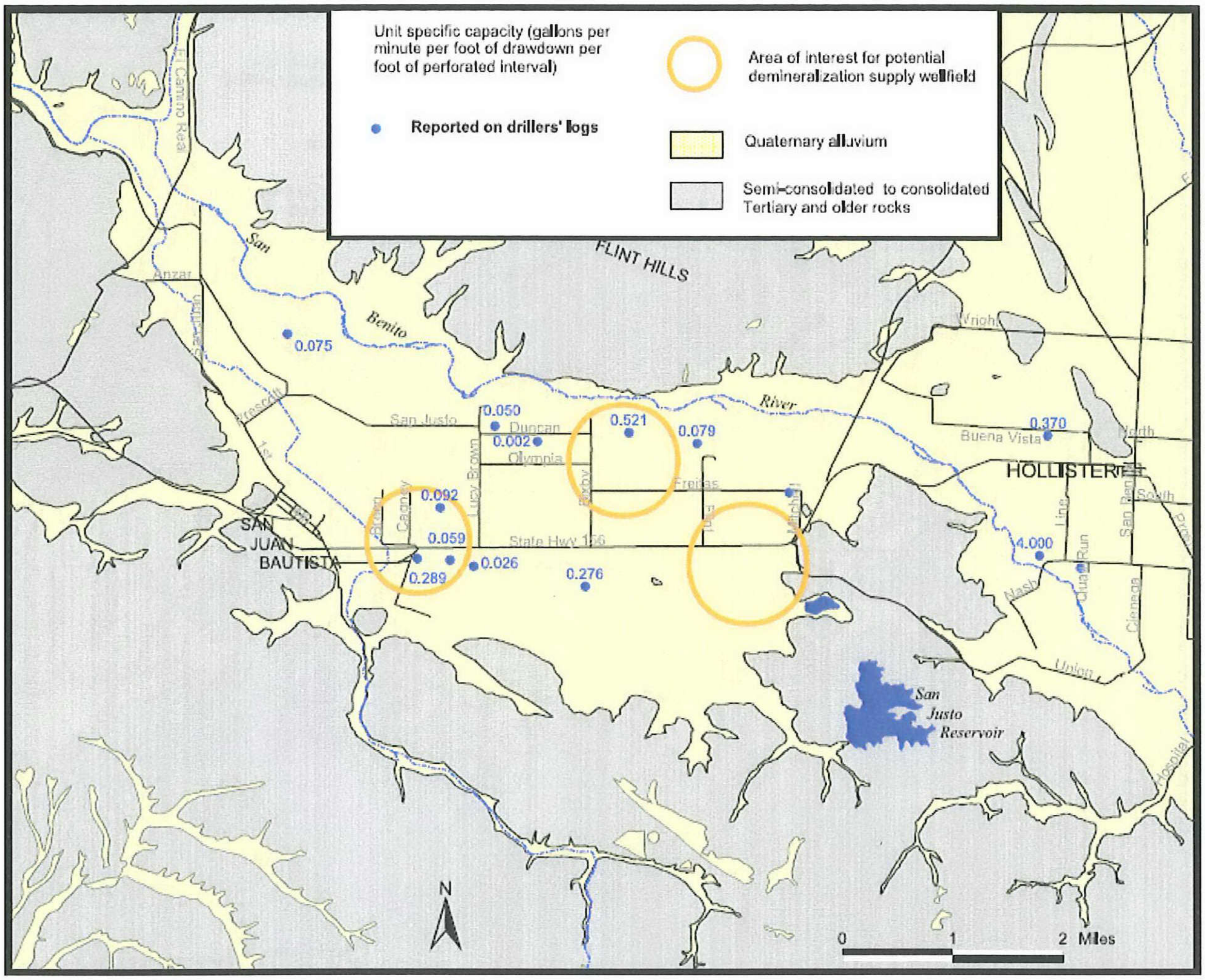


Figure 2-5 shows the unit specific capacity of 12 wells in or near the San Juan Valley. These data represent all values reported on drillers' logs maintained by SBCWD. Normalizing the well yields for drawdown and screen length results in a more comparable data set, but the number of points is too small to support any conclusions regarding basin-wide geographic variations.

Figure 2-5: Unit Specific Capacity of San Juan Valley Wells

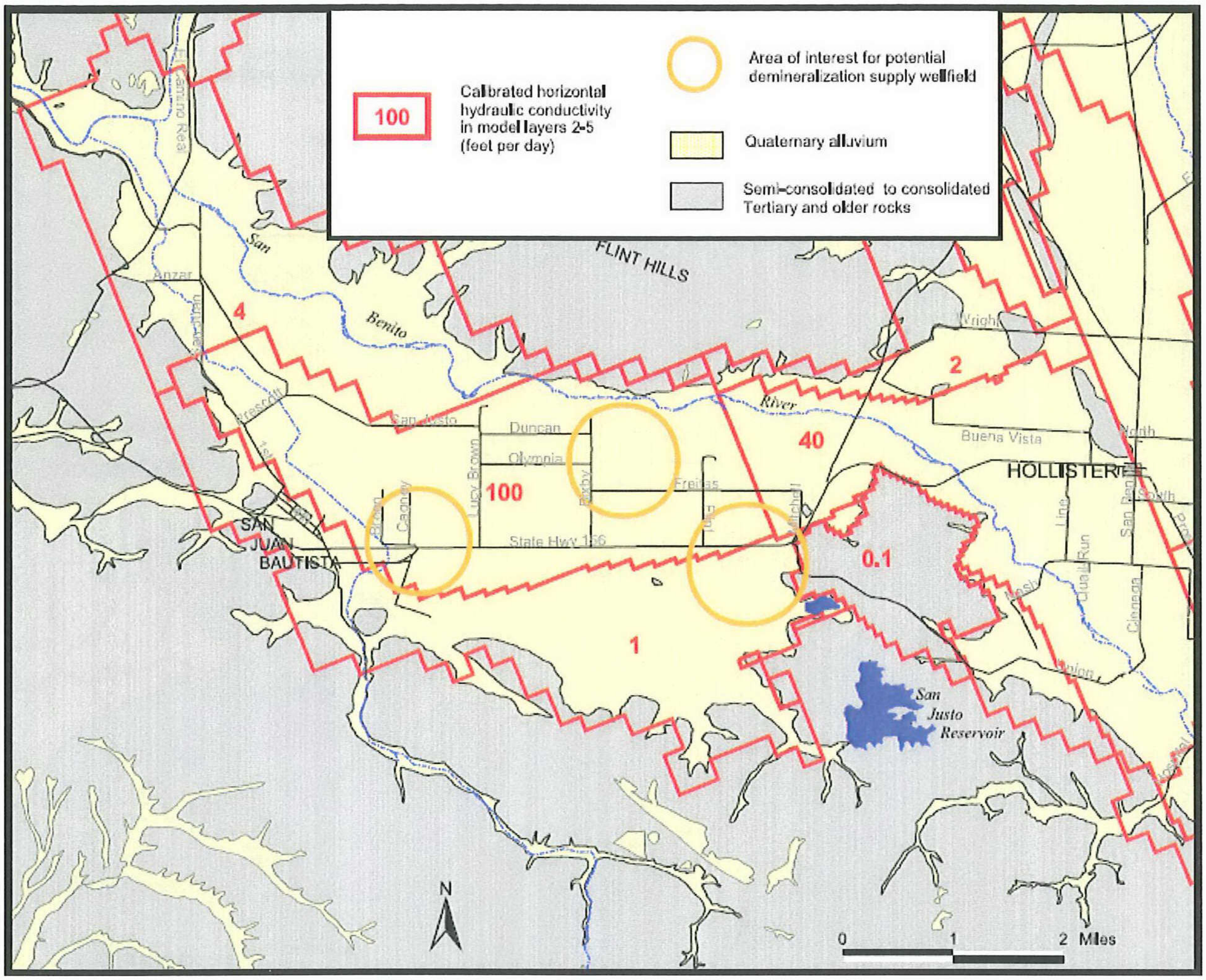


2.4.2 Basin Hydraulic Conductivity

The hydraulic conductivity of an aquifer represents the inverse of its "resistance" to groundwater movement. It is difficult to measure directly, so initial estimates in the groundwater model were adjusted during model calibration to obtain a better match between simulated and measured water levels. The conductivity values represent the bulk characteristics of the basin sediments rather than specific estimates for the more permeable layers that convey most of the flow.

To match existing upward head gradients and flowing wells to the northwest of San Juan Bautista, a transition from high conductivity in the central portion of the valley to a much lower value in the northwest portion of the valley was required, as shown in Figure 2-6. The central portion of the valley was calibrated with a conductivity of 100 feet per day while the northwest portion was calibrated at 4 feet per day. The high conductivity zone conveys groundwater rapidly from where the San Benito River enters the valley, and the "dead end" at the transition forces that water to flow upward to shallow layers and the ground surface. Two of the three proposed wellfield locations are within the high conductivity region in the center of the valley. The Union Road site is at the transition between high conductivity and apparent low-conductivity zones in the southeastern part of the valley. The precise location and abruptness of this transition are speculative and, given this lack of information, the Union Road site is more uncertain than the Freitas-Bixby and Cagney Road sites, both of which are in the high-conductivity zone.

Figure 2-6: Hydraulic Conductivity Variations in San Juan Valley


100
Calibrated horizontal hydraulic conductivity in model layers 2-5 (feet per day)
Area of interest for potential demineralization supply wellfield
Quaternary alluvium
Semi-consolidated to consolidated Tertiary and older rocks
FLINT HILLS
San
Benito
River
4
2
40
100
1
0.1
Anzar
Prescott
San Justo
Duncan
Olympia
Lucy Brown
Freitas
State Hwy 156
Buena Vista
Wright
SAN JUAN BAUTISTA
HOLLISTER
San Justo Reservoir
N
0
1
2 Miles

2.4.3 Nearby RWQCB Regulated Sites

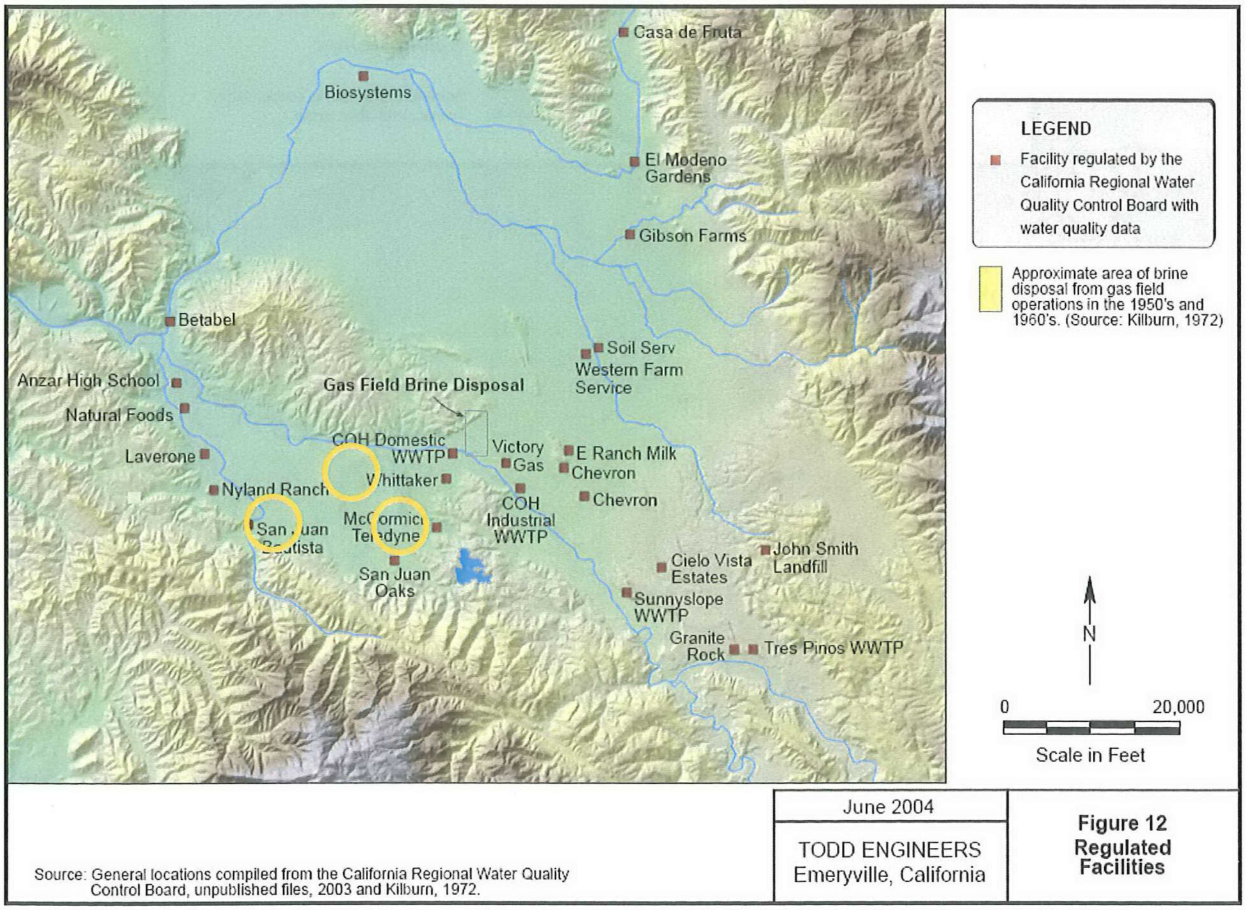
As shown in Table 2-3, each of the three sites is located in moderate proximity to a Regional Water Quality Control Board (RWQCB) regulated site. The locations of these sites, as well as others in the Gilroy-Hollister groundwater basin are shown in Figure 2-7. The regulated sites that have potential impacts on the groundwater sources for these three locations are described in detail in *Development of a Water Quality Monitoring Program for the Hollister Groundwater Basin* prepared for SBCWD by Todd Engineers in June 2004 and in the *Annual Groundwater Report for Water Year 2005*, prepared for SBCWD by Gus Yates, RG CHg. In general, these sites can be characterized as follows:

- McCormick/Teledyne Site – Historical activities at this site included the use of perchlorate and trichloroethylene (TCE), both of which have historically seeped into groundwater. The site has been undergoing monitoring and pilot testing of *in-situ* treatment methods in an effort to establish baseline conditions and set the stage for full-scale future remediation. Downstream groundwater monitoring is limited and little is known of the extent of the contamination.
- Whittaker Site – This site was previously used in ordnance manufacturing. High concentrations of perchlorate, TCE and volatile organic compounds (VOCs) are found throughout the site, and several offsite supply wells have been impacted. Contamination has been detected more than 1,000 feet horizontally from the site as well as at depths ranging from 160 feet to 270 feet. Several characterization, treatment and remediation methods have been implemented at the site

since the mid-1990s and water quality solutions for several of the impacted offsite wells have been implemented.

- City of Hollister Domestic Wastewater Treatment Plant (DWTP) – Operations at this site include the use of a pond system for wastewater treatment followed by percolation ponds for disposal of the treated wastewater. At this location, the primary regional groundwater flow path is to the west, into the San Juan sub-basin. The wastewater contains high concentrations of TDS, sodium and chloride, as well as other constituents commonly found in treated wastewater. The water quality impacts of the percolation operations are most evident in shallow groundwater near the facility.
- City of San Juan Bautista Wastewater Treatment Plant (WWTP) – This facility utilizes a sequencing batch reactor treatment system followed by ultraviolet disinfection prior to disposal of the treated wastewater into a small tributary of San Juan Creek which tends to gain water from groundwater inflow. Also, the discharge point is located to the southwest side of the San Andreas Fault which acts as a partial barrier to groundwater flow. These two circumstances indicate that little, if any, of this wastewater enters the San Juan sub-basin and would have no impact on a groundwater supply well located in the area.
- San Juan Oaks Golf Course – This facility operates a small septic system leach field on site. The small volume of waste disposed makes this unlikely to impart any impacts on the groundwater basin.

Figure 2-7: RWQCB Regulated Sites



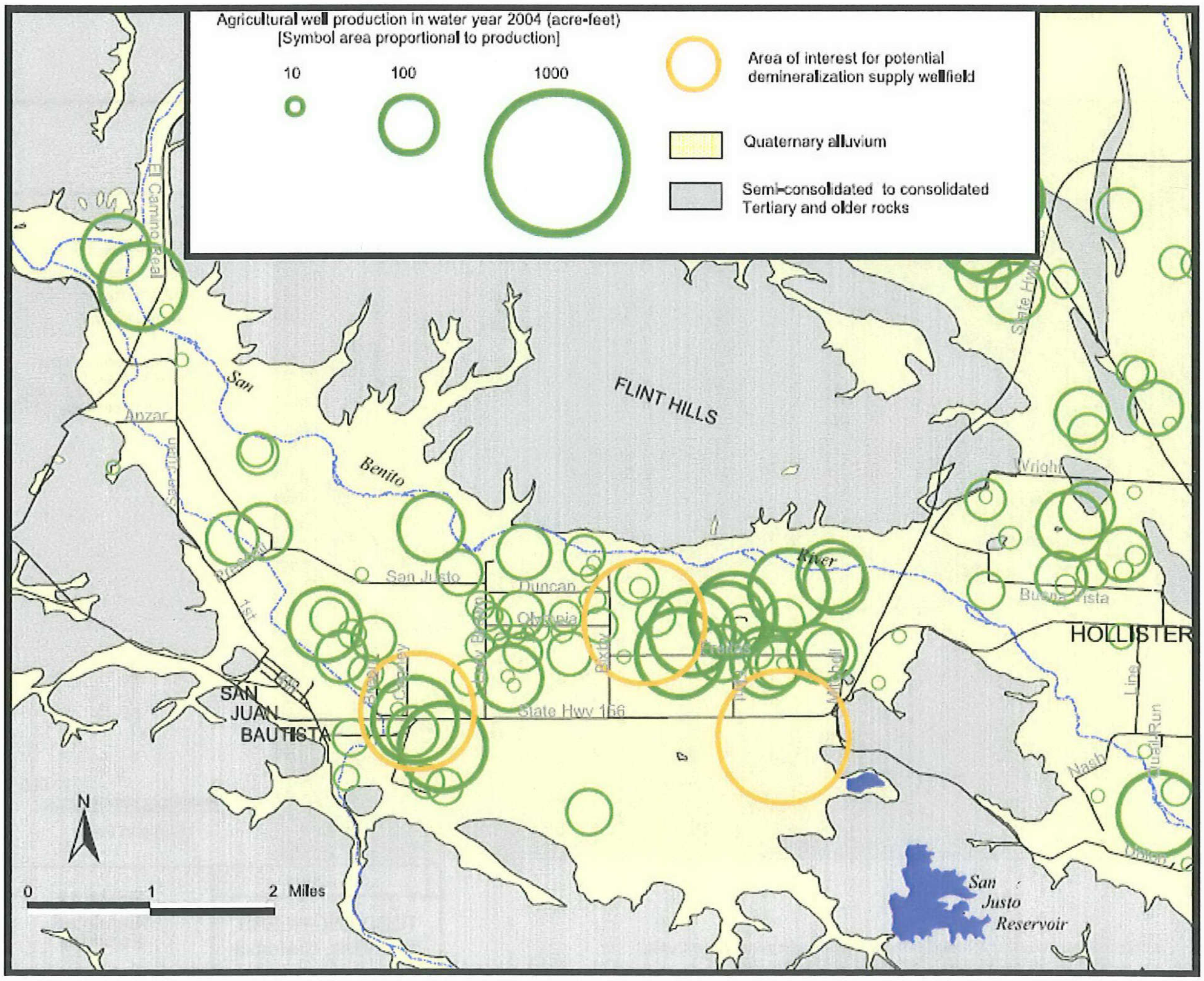
Source: General locations compiled from the California Regional Water Quality Control Board, unpublished files, 2003 and Kilburn, 1972.

The gas field brine disposal area shown in Figure 2-7 has minimal documentation and additional investigation into this area is recommended if deep well injection is a recommended concentrate management strategy.

2.4.4 Proximity to Existing Wells

The number of existing wells in close proximity to any new demineralization supply wells can have an impact on the well yield due to interactions between the drawdown cones for each well. To identify this interference, existing agricultural wells were identified and circles representing the production from each well were plotted. Figure 2-8 shows the distribution of these large wells throughout the San Juan Valley with the potential supply wellfield sites overlaid on that map. Both the Union Road and Freitas-Bixby sites have areas without substantial interference from existing wells that could be potential sites for development of a demineralization supply wellfield. The Cagney Road area has several large agricultural wells nearby. To minimize potential interference, the site analyzed in the groundwater model was shifted slightly to the north, away from the existing wells. Domestic supply wells are not shown on this map as their yields are substantially smaller than agricultural wells. There are currently two active M&I wells in the San Juan Valley, both are owned by the City of San Juan Bautista and are within close proximity to the Cagney Road location. The combined supply from these two wells is approximately 440 AFY.

Figure 2-8: Agricultural Well Production During Water Year 2004


Agricultural well production in water year 2004 (acre-feet)
[Symbol area proportional to production]
10
100
1000
Area of interest for potential demineralization supply wellfield
Quaternary alluvium
Semi-consolidated to consolidated Tertiary and older rocks
El Camino Real
Anzar
San
Benito
River
FLINT HILLS
San Justo
Duncan
Olympia
Bixby
State Hwy 156
State Hwy
Wright
Buena Vista
HOLLISTER
Line
Nash
Union
Quail Run
1st
SAN JUAN BAUTISTA
N
0
1
2 Miles
San Justo Reservoir

2.5 Wellfield Design

Developing groundwater wellfield concepts was completed using the calibrated local groundwater model. This model allows variations in wellfield location and characteristics and can provide information on the impacts of increased pumping on water levels, salinity migration and the sub-basin water balance. This Section summarizes the criteria used to establish the basis for the groundwater model simulations. Section 2.6 summarizes the modeling results.

2.5.1 Annual Extraction Volume

The quantity of groundwater that can be extracted from the San Juan Valley sub-basin for demineralization is a balance between municipal needs and groundwater basin conditions. The groundwater conditions primarily impacted by increased pumping are water levels and groundwater discharge to San Juan Creek and the San Benito River. At higher water levels, groundwater begins to discharge as baseflow in San Juan Creek and the San Benito River, both of which enter the Pajaro River at the far western end of the sub-basin. In the 15 years since import of CVP water commenced, water levels have risen and groundwater discharge to streams now averages approximately 5,000 AFY. This outflow is currently the only natural salt removal mechanism available for the basin and maintaining this discharge has been necessary to prevent severe long-term increases in groundwater salinity.

With the addition of groundwater demineralization in the San Juan Valley, an additional means of salt removal would be created, potentially exceeding the current salt export quantities. Each volumetric unit of groundwater extraction would yield a salt removal roughly offsetting the required volumetric salt removal from stream discharges. Additional salt management benefits would be provided as the wastewater treatment facilities that percolate into the San Juan Valley groundwater basin would have a decreased salt loading from a reduced level of TDS in the drinking water supply and the offset of water softener use in the potable water service area. There may be additional needs for stream discharge for habitat or environmental requirements in the San Benito River or San Juan Creek; however these specific needs are not planned to be addressed at this stage of the project. Annual pumping volumes ranging from 1,000 AFY to 3,000 AFY were initially identified as providing an appreciable quantity of water for municipal uses while minimizing the risk of returning the basin to an overdraft condition. These annual extraction volumes were tested in the groundwater model. Other larger volumes of groundwater extractions will be evaluated as part of the Hollister Urban Area Water and Wastewater Master Plan and these results will also be summarized.

2.5.2 Well Spacing

Based on groundwater model assumptions and previous knowledge of the groundwater basin, a set of wellfield design criteria was developed. These criteria are used to identify the required number of wells, the arrangement of the wellfield and the sizing of wells and pipelines. These main criteria are identified in the following list and are described in the subsequent paragraphs.

- Operational period (hours per day; days per year)
- Total wellfield capacity
- Individual well yields
- Number of wells
- Well depth
- Pumping head
- Well interference
- Well spacing
- Wellfield arrangement

- General location

The wellfield is assumed to operate year-round over a 16-hour period each day. This would allow cyclic recovery of water levels at the wells. The eight-hour down-time would provide a set time frame for maintenance and repairs when required. To operate the wells using this strategy the demineralization facility will require storage or multiple wells operating on staggered schedules. For the demineralization facility to operate continually during the day, the preferred operational mode for a demineralization facility, raw groundwater storage would be required to maintain a constant feed to the treatment system.

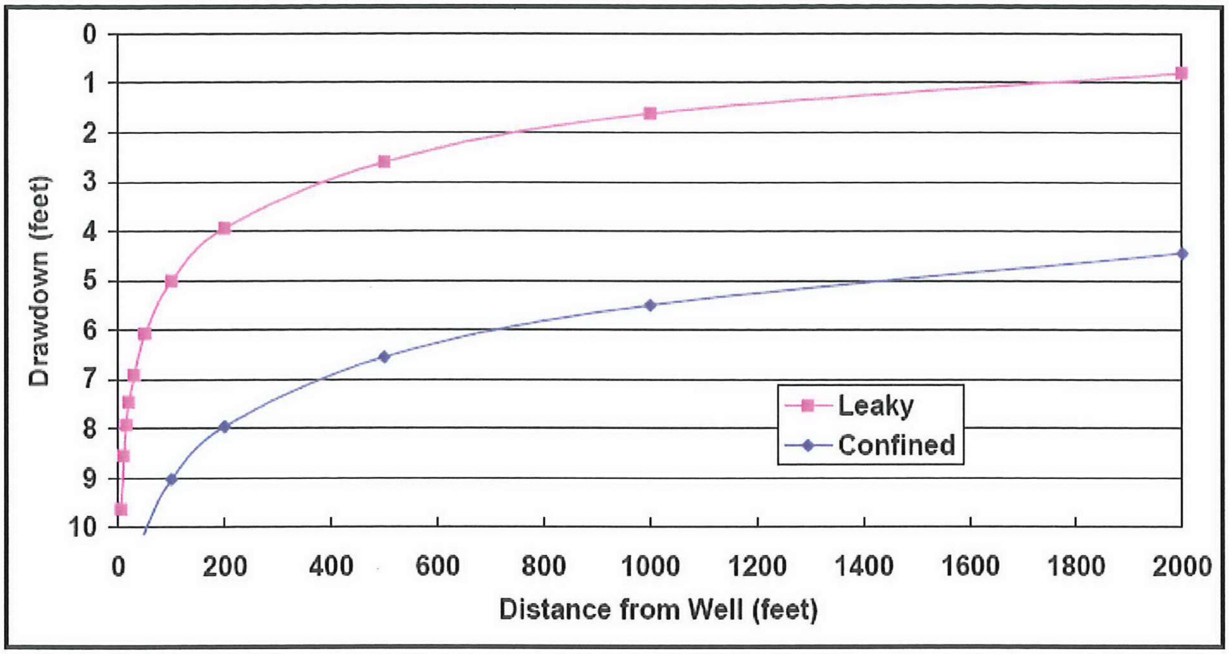
To provide 1,000 to 3,000 AFY of groundwater for demineralization while pumping 16 hours per day, the wellfield will need to have an instantaneous capacity of 930 to 2,790 gallons per minute (gpm). Utilizing data from existing wells in the San Juan Valley, the average yield of a deep well (300 to 500 feet deep) is 400 to 500 gpm and the average yield of an intermediate depth well (50 to 150 feet deep) is 200 to 250 gpm. To achieve the required wellfield capacity, 2 to 7 deep wells or 4 to 14 intermediate depth wells would be required. The differential qualities of the deep groundwater and the intermediate depth groundwater may provide an incentive to exclusively use one or the other. If minimization of installed infrastructure is a priority, then deep wells would reduce the number of wells to be installed.

Each well will need a pump and power supply adequately sized to produce water at the desired rate under the prevailing conditions of lift and pressure. The following list summarizes the components of total dynamic head (TDH) against which the pumps must operate:

- Static lift to ground surface (20 to 30 feet)
- Drawdown during pumping (25 to 30 feet)
- Velocity head (negligible)
- Friction losses in pipes and fittings (assume 20 feet)
- Elevation change between wells and treatment facility (assume 0 feet)
- Delivery pressure at treatment plant (10 pounds per square inch [psi], or 23 feet)

These elements sum to a TDH of approximately 100 feet. This pumping requirement is in addition to the pumping necessary to drive the demineralization process and that necessary for distribution through the potable water system, both of which are planned to be provided separately. One additional component of the groundwater well TDH is drawdown from nearby wells, or well interference. As the separation between wells increases, the mutual drawdown decreases to a point where it is negligible compared to other pumping requirements. A major factor affecting drawdown is the degree of aquifer confinement, which relates to the continuity of the aquitards separating the pumped aquifer from the water table. In the San Juan Valley the aquitards are leaky, discontinuous and sufficiently thin so that vertical flow from the water table to the pumped aquifers is significant. Figure 2-9 shows the impact of distance from the well on the drawdown for both leaky and confined aquifers. For leaky aquitards, the drawdown is approximately 4 feet at 200 feet away and 3 feet at 400 feet away which, in the context of total system pumping requirements, is minimal and indicates that this distance is adequate spacing between wells.

Figure 2-9: Drawdown v. Distance Curves for Leaky and Confined Aquifers



Finally, the arrangement of the wells in a wellfield can vary. Two arrangements under consideration are a cluster of wells and a row of wells. A row would, in general, have the same infrastructure requirements as a cluster of wells but could provide improved groundwater management and property acquisition benefits. A row of wells also spreads out the pumping stresses more than a cluster of wells, minimizing local drawdown impacts while achieving the same regional water budget and water level effects.

2.6 Preliminary Groundwater Modeling

Using the information presented in earlier sections, wellfields were modeled and simulated over a 30-year period represented by hydrologic conditions that occurred during water years 1975 to 2004. The initial conditions for the simulations corresponded to conditions present in September 2004. Additional documentation of the groundwater model is included as Appendix B. The following sections summarize the simulation inputs and results.

Only the Freitas-Bixby and Cagney Road sites were carried forward to the modeling analysis. The Union Road site was not modeled because several factors made it clearly less desirable or more uncertain than the other sites. These factors included the lack of well yield and water quality data in that area, the risk of encountering low-permeability aquifer materials, the likelihood of accelerating the movement of the Whittaker contaminant plume, and the possibility of entraining effluent percolated at the DWTP.

2.6.1 Simulation Parameters

The Freitas-Bixby and Cagney Road sites were each configured as rows of wells along existing roads (Bixby and Cagney) as far as practical from nearby areas of existing concentrated pumping. The simulations tested two values for each of three variables:

- Location: Freitas-Bixby or Cagney Road
- Annual extraction volume: 1,000 AFY or 3,000 AFY
- Well depth: Intermediate depth (screened from 50 to 150 feet) or deep (screened 150 to 500 feet)

These three parameters can be combined into eight distinct combinations. Five of these combinations were initially simulated to test the relative importance of each variable. Based on the results from these five simulations, and the similarities in the impacts on various parameters, the final three simulations were judged to be unnecessary. Table 2-4 summarizes the sets of parameters that defined each model run and the figure numbers that show the results. Model run 46 represents the existing conditions in the basin.

Table 2-4: Groundwater Basin Model Run Summary

Model Run ID#	46	54	55	57	58	61
Wellfield Location	None	Freitas-Bixby	Freitas-Bixby	Freitas-Bixby	Cagney Road	Cagney Road
Annual Pumping (AFY)	0	1,000	3,000	3,000	1,000	3,000
Well Depth	NA	Int.	Int.	Deep	Int.	Deep
Number of Wells	0	4	12	6	4	6
Hydrographs	Figure 2-11	Figure 2-14	ND	Figure 2-15	Figure 2-16	Figure 2-17
Elevation Contours	Figure 2-12	Figure 2-18	ND	Figure 2-19	Figure 2-20	Figure 2-21
TDS Contours	Figure 2-13	Figure 2-22	Figure 2-23	Figure 2-25	Figure 2-25	Figure 2-26
Groundwater Budgets	Figure 2-27 & Figure 2-28	Figure 2-27	Figure 2-28	Figure 2-28	Figure 2-27	Figure 2-28
Horizontal Groundwater Flow Paths	ND	ND	Figure 2-29	Figure 2-31	ND	Figure 2-33
Vertical Groundwater Flow Paths	ND	ND	Figure 2-30	Figure 2-32	ND	Figure 2-34

Notes:
NA = Not Applicable, Int. = Intermediate, ND = Not Developed

For the purposes of the modeling, the well spacing was selected on the basis of the well interference analysis in Section 2.5. Intermediate wells were assumed to be spaced 300 feet apart and deep wells were assumed to be spaced 600 feet apart. Land and water use remained equal to existing conditions in all of the simulations.

2.6.2 Existing Conditions – Run 46

Model run 46 represented existing or "no-project" conditions and served as the reference simulation to which the various with-project simulations were compared. The model outputs used to describe differences between existing and with-project simulations were:

- Hydrographs of simulated groundwater elevations in model layers 1 (shallowest) and 5 (deepest) at the well locations identified in Figure 2-10
- Groundwater elevation changes throughout the San Juan Valley in model layers 1 and 5
- Contours of TDS concentration changes throughout the San Juan Valley in model layers 1 and 5
- Bar charts showing groundwater budgets in the San Juan sub-basin
- Horizontal and vertical groundwater flow paths

The results from the model run simulating existing conditions can be seen in Figure 2-11, Figure 2-12 and Figure 2-13. The groundwater gradient is from southeast to northwest approximating the direction of groundwater flow in the area. In some areas near San Juan Bautista, the groundwater level approaches or exceeds the ground surface elevation, consistent with the presence of flowing wells and wetlands in that area. Another prominent result is the band of low-TDS groundwater along creek and river reaches that tend to recharge the groundwater basin. Aside from these localized creek effects, the general trend in both shallow and deep layers is higher TDS concentrations in the southeastern portion of the valley decreasing towards the northwestern portion.

Figure 2-10: Simulation Wellfield and Monitoring Well Locations

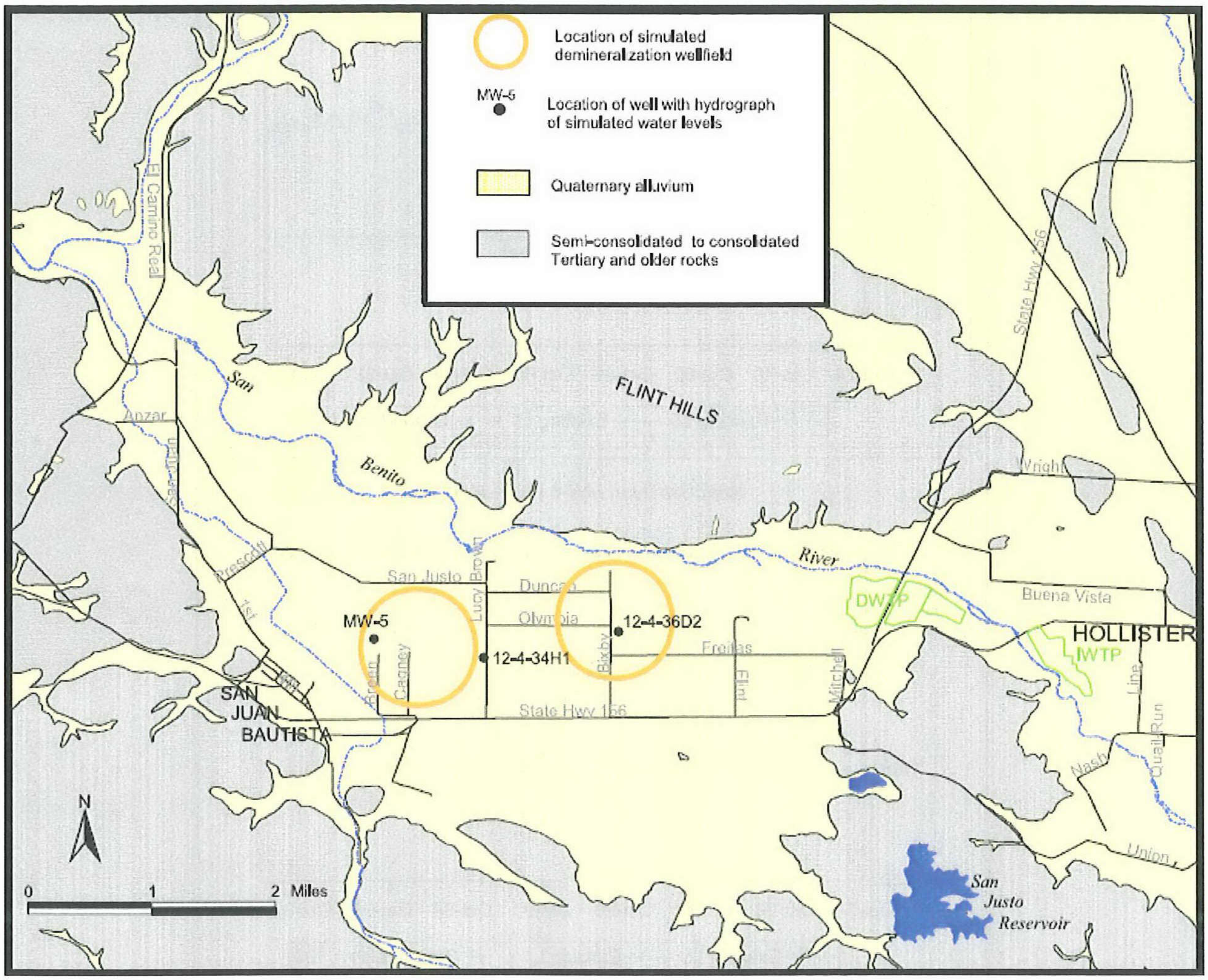


Figure 2-11: Groundwater Elevations at Monitoring Wells - Run 46

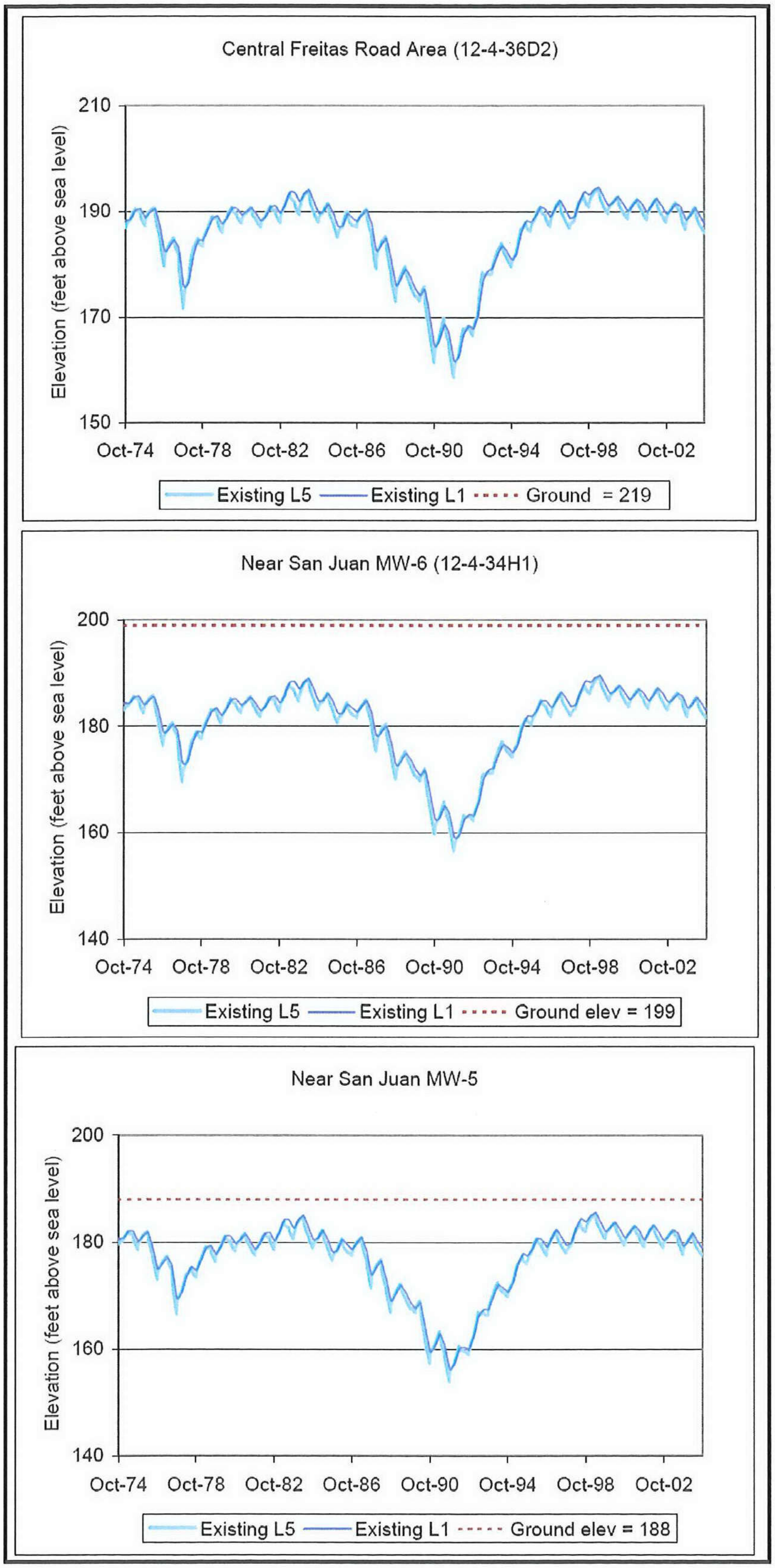
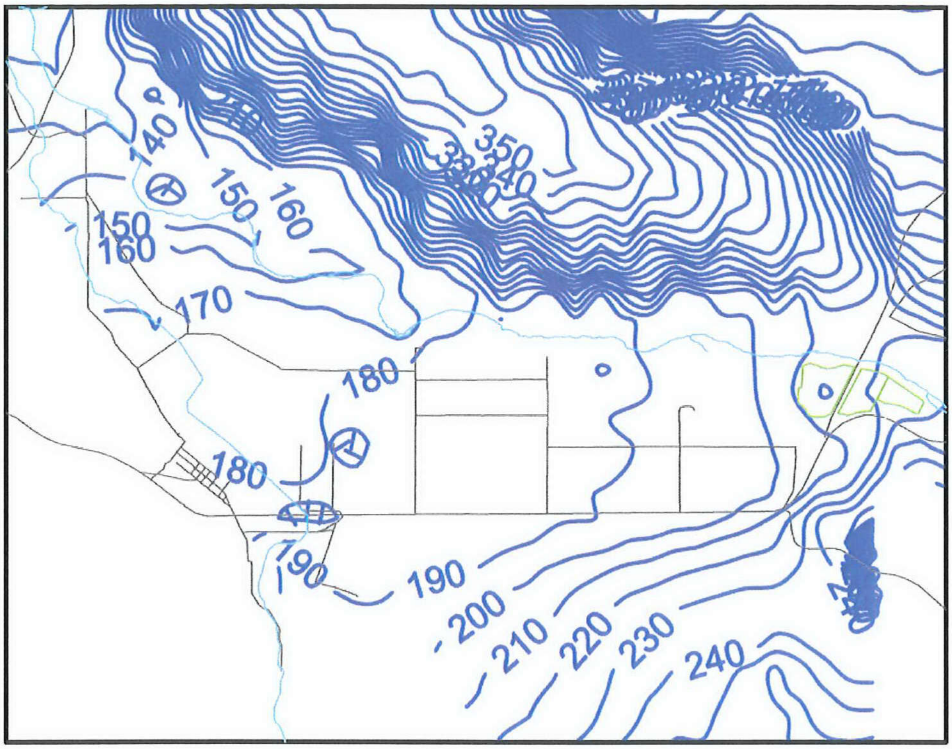


Figure 2-12: Groundwater Elevation Contours - Run 46

A. Model Layer 1



B. Model Layer 5

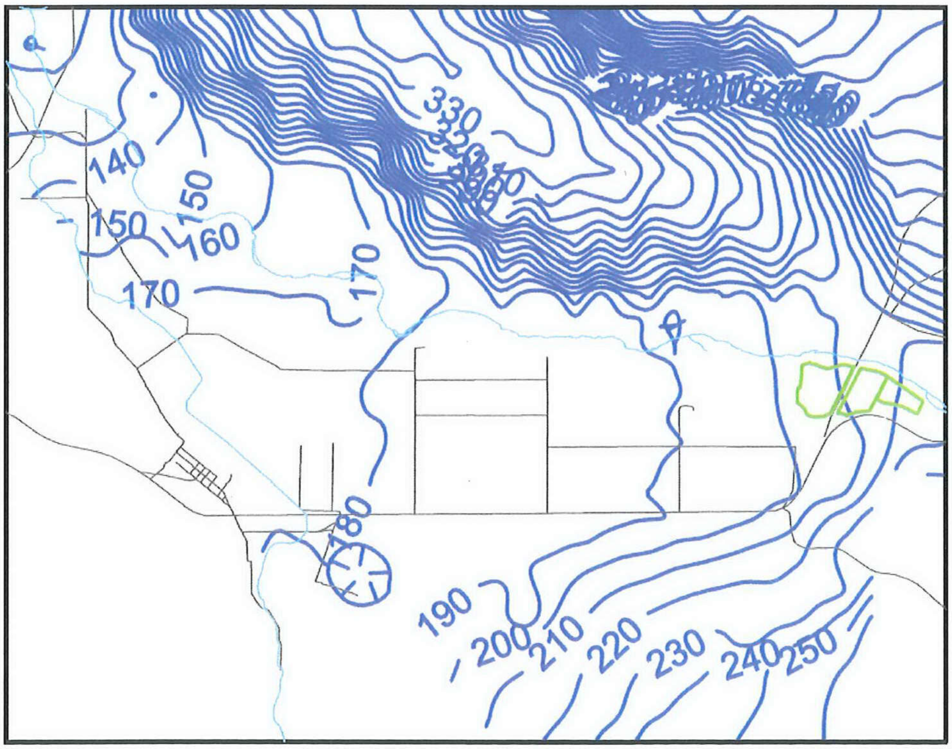
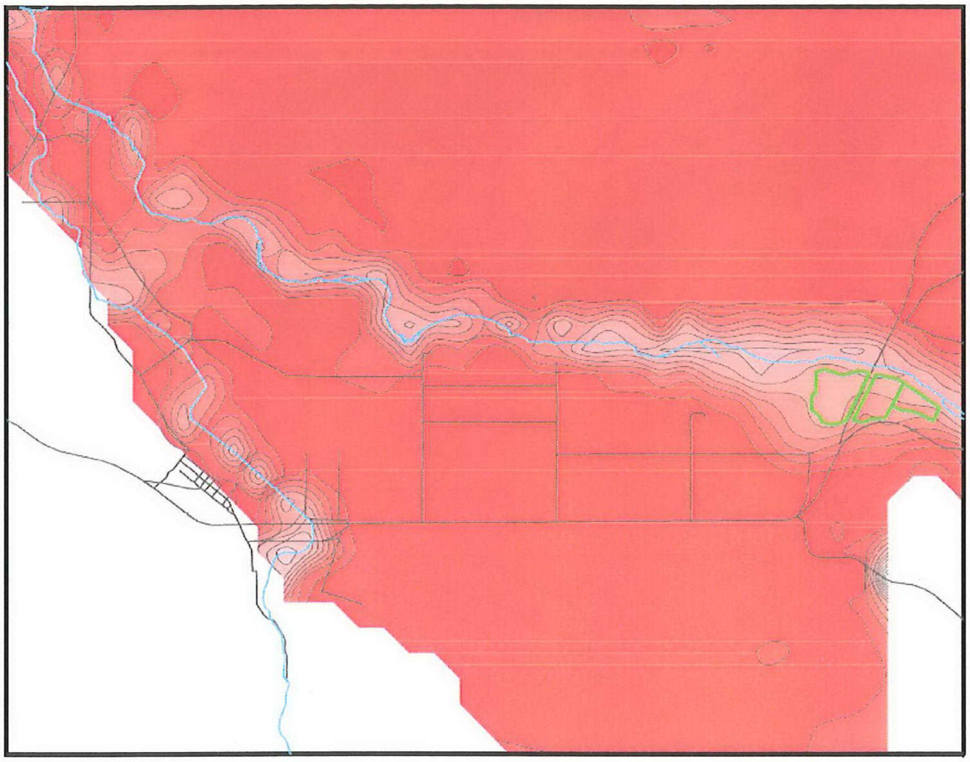
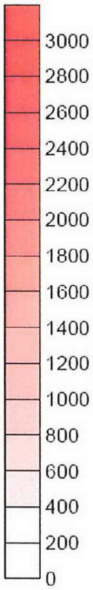
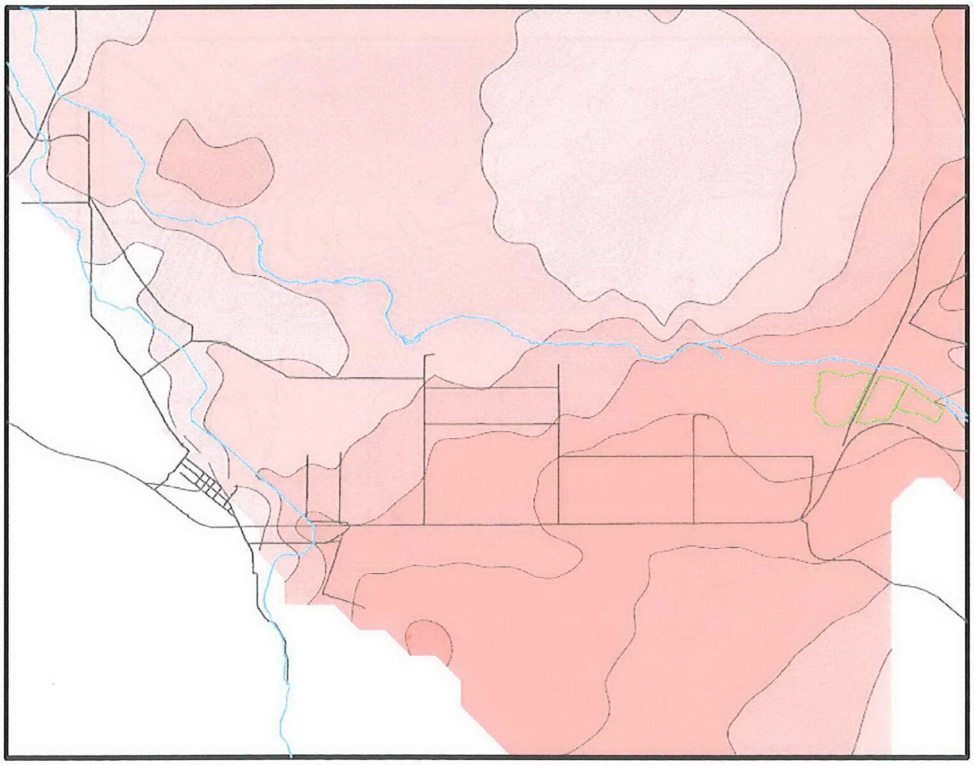


Figure 2-13: Groundwater TDS Concentration Contours - Run 46





B. Model Layer 5



2.6.3 Water Level Impacts: Hydrographs

Runs 54, 57, 58 and 61 demonstrated had varying impacts on groundwater levels in the three monitoring wells (shown in Figure 2-10) used to track water level changes in the San Juan Valley. Figure 2-14 (run 54), Figure 2-15 (run 57), Figure 2-16 (run 58) and Figure 2-17 (run 61) show the hydrographs for model layers 1 (dark blue line) and 5 (light blue line) for the indicated demineralization pumping simulation as compared to persistence of existing conditions in model layers 1 (red line) and 5 (orange line). Examining these four figures together reveals the following patterns:

- Wellfield drawdown is approximately twice as large for 3,000 AFY of production compared to 1,000 AFY of production. The typical proportional relationship between pumping rate and drawdown is moderated by leaky aquifer conditions and the presence of the San Benito River as a head-dependent recharge boundary.
- The drawdown spreads out over a fairly large area. Drawdown at the simulated wellfield site is only slightly greater than at the non-simulated site. The geographic extent of drawdown is revealed more fully in the water-level contour plots shown in Section 2.6.4.
- Drawdown increases gradually during the first 5 years of wellfield operation, and then reaches a quasi-steady state. Drawdown increases slightly during droughts, presumably because of decreased ability to induce seepage from the river, then returns to the pre-drought level. Drawdown near the wellfield is 3-7 feet for a production rate of 1,000 AFY and 6-12 feet for a production rate of 3,000 AFY.
- The wellfield affects shallow and deep aquifers approximately equally, regardless of whether the pumping is from intermediate-depth or deep wells. In other words, wellfield pumping does not substantially alter the vertical water-level gradients, but it creates a geographically extensive cone of depression.
- Even with a maximum drawdown of 12 feet near the center of a wellfield producing 3,000 AFY, simulated water levels are still much higher than historical water levels prior to the importation of CVP water. For example, the minimum simulated water level at the Freitas-Bixby wellfield site was 145 feet above sea level (top graph in Figure 2-15). The historical water level at that site in the early 1990s was approximately 120 feet above sea level. Near well 12-4-34H1 (middle graph on Figure 2-17), the minimum simulated water level of 143 feet was 43 feet higher than the historical water level in the early 1990s. There are no historical water level data near well MW-5, which had a minimum simulated water level of 140 feet (bottom graph on Figure 2-17). The closest well with historical data (12-4-28R1, 0.3 mile to the northwest) had a water level of approximately 120 feet in the early 1990s.

Figure 2-14: Groundwater Elevations at Monitoring Wells – Run 54 [Freitas-Bixby; Intermediate depth; 1,000 AFY]

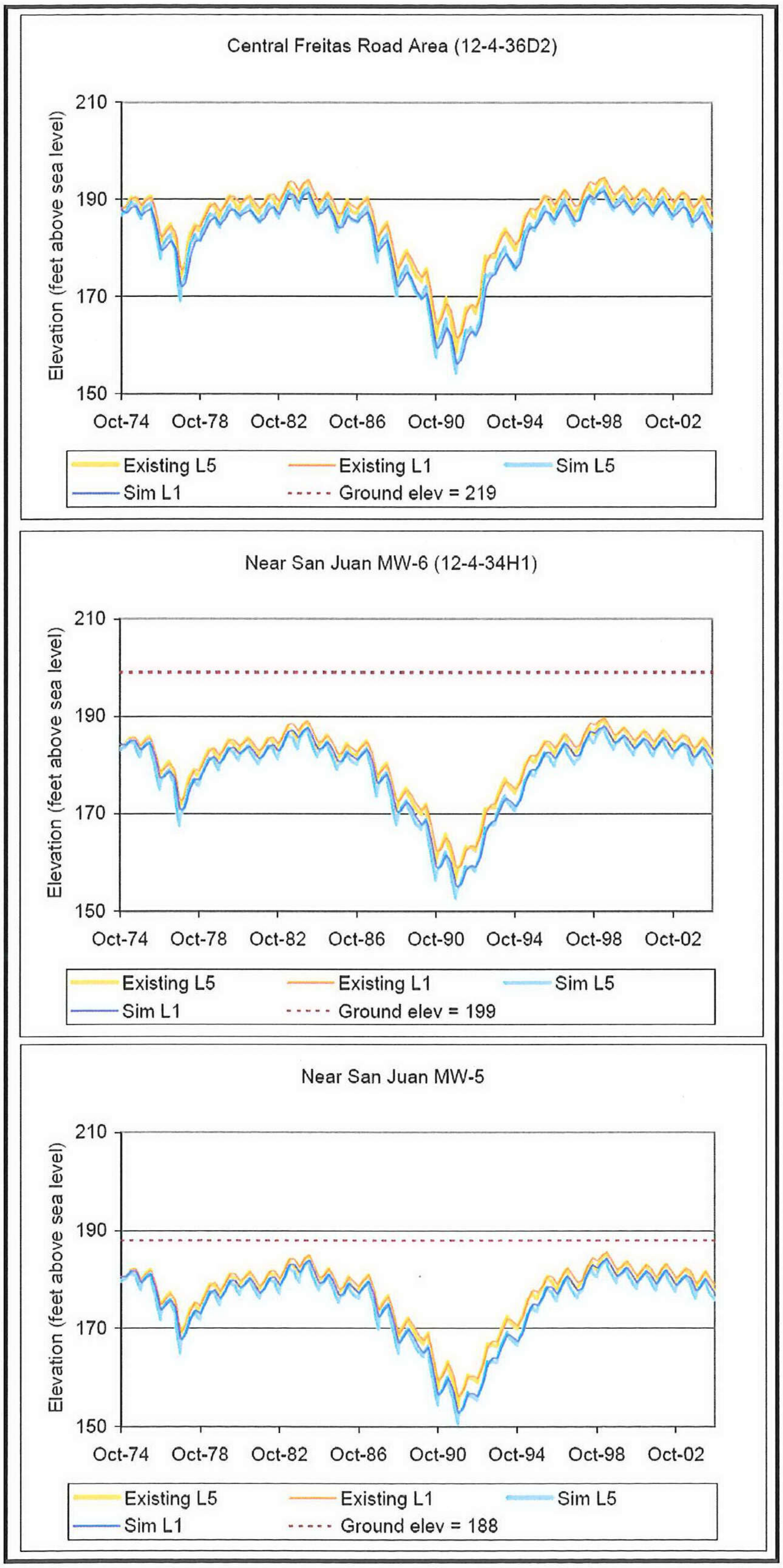
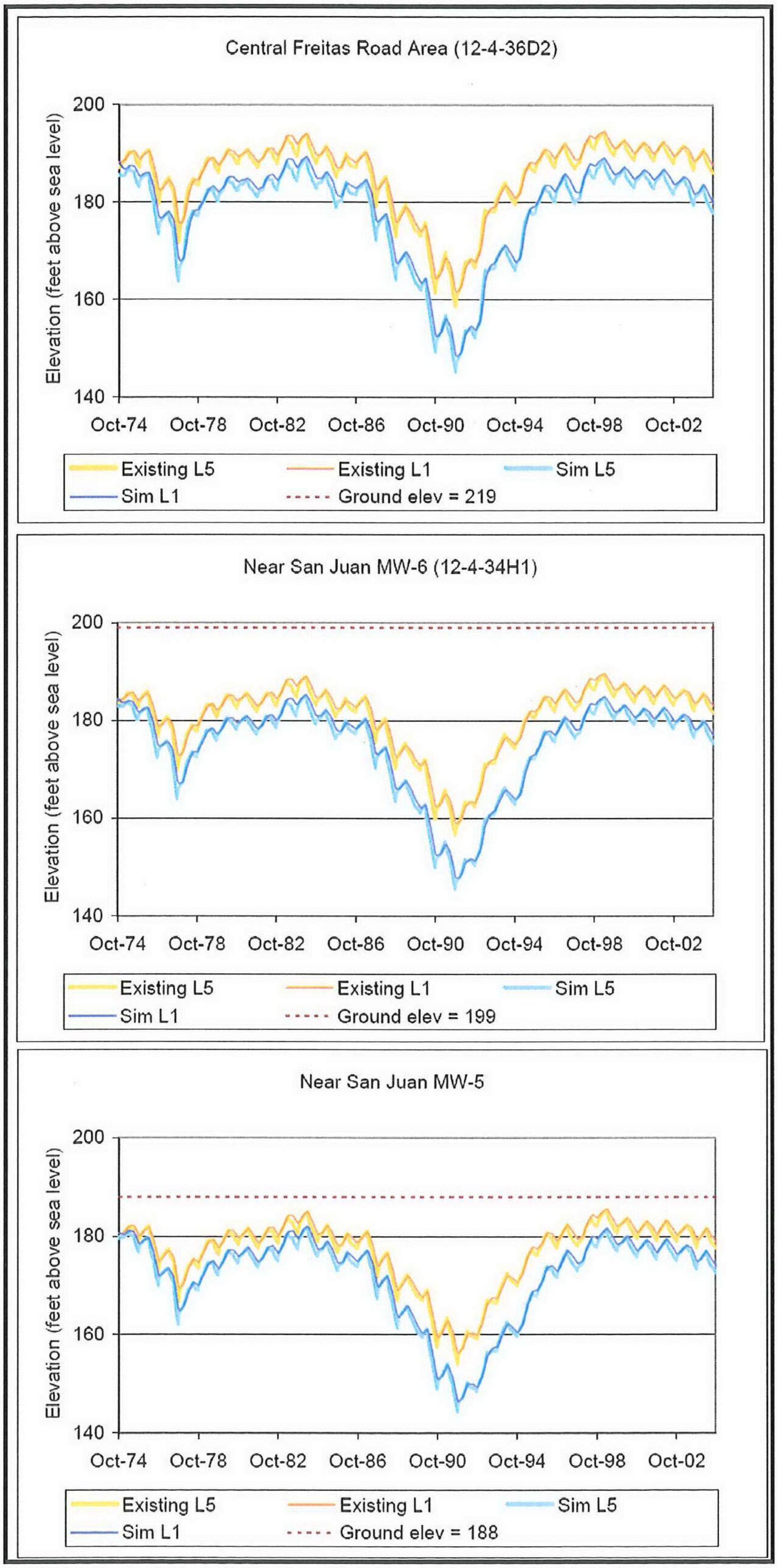


Figure 2-15: Groundwater Elevations at Monitoring Wells - Run 57
[Freitas-Bixby; Deep; 3,000 AFY]


Central Freitas Road Area (12-4-36D2)

Near San Juan MW-6 (12-4-34H1)

Near San Juan MW-5

Figure 2-16: Groundwater Elevations at Monitoring Wells - Run 58 [Cagney Road; Intermediate depth; 1,000 AFY]

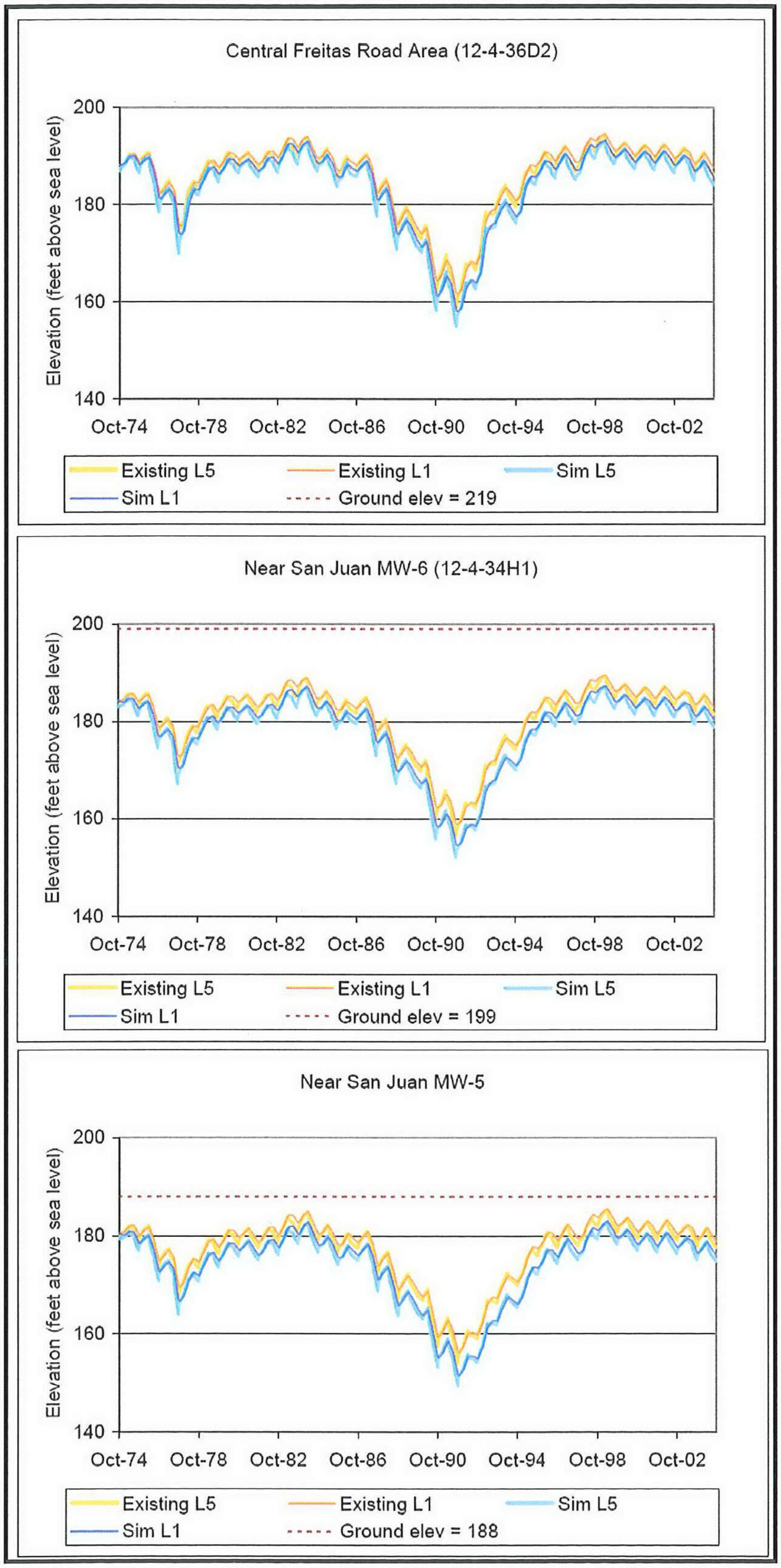
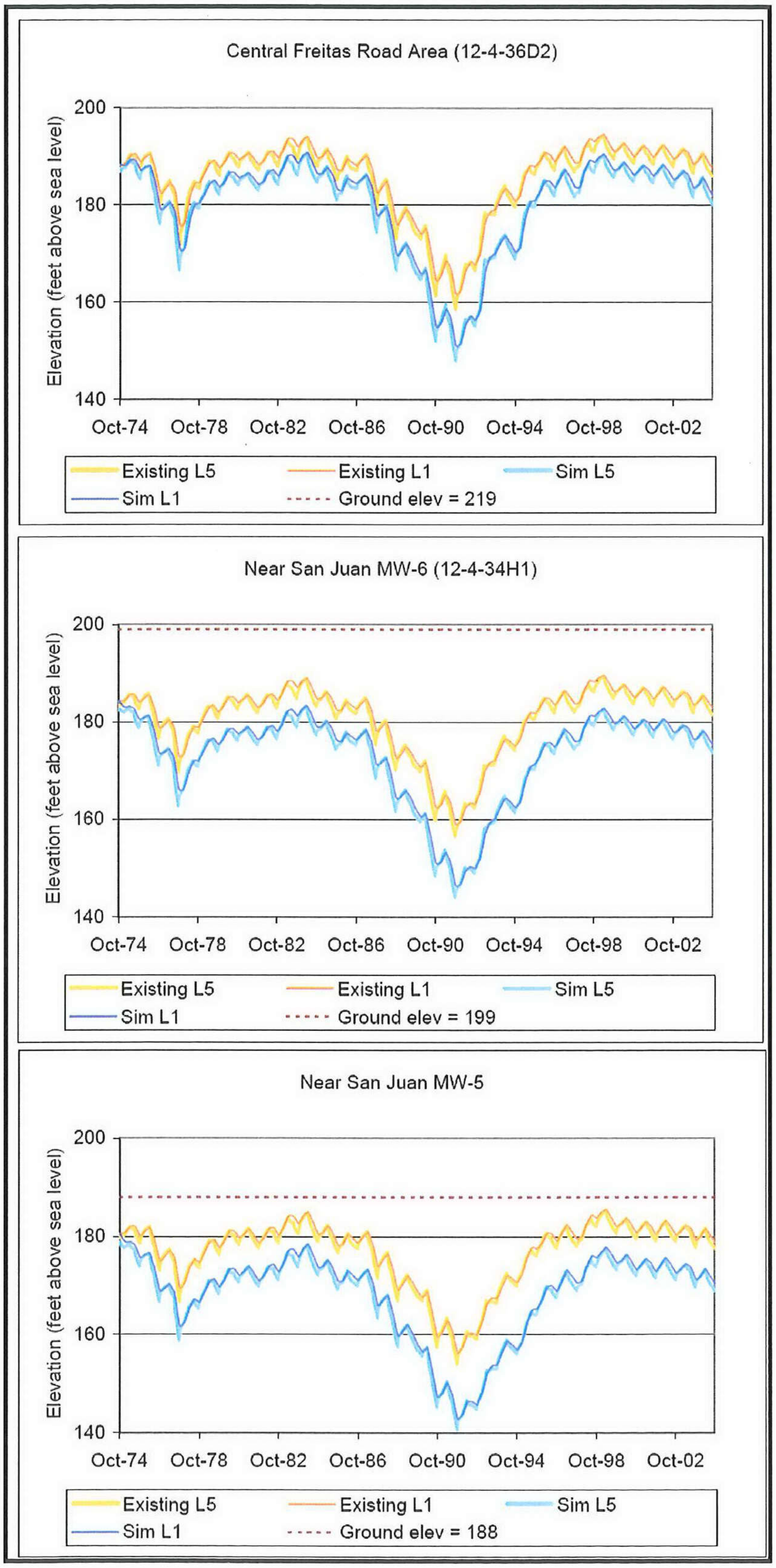


Figure 2-17: Groundwater Elevations at Monitoring Wells - Run 61 [Cagney Road; Deep; 3,000 AFY]


Central Freitas Road Area (12-4-36D2)

Near San Juan MW-6 (12-4-34H1)

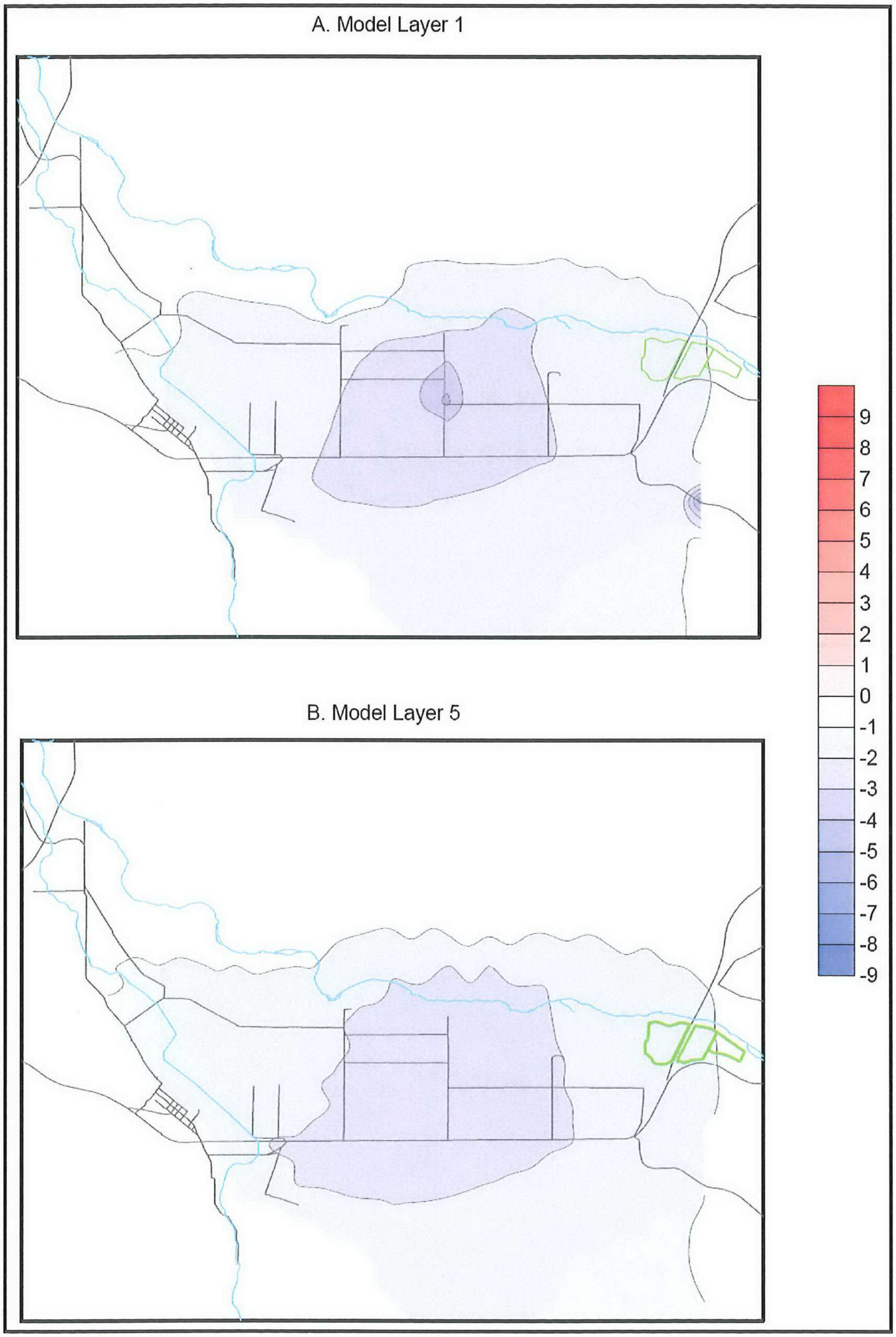
Near San Juan MW-5

2.6.4 Water Level Impacts: Contours

Figure 2-18, Figure 2-19, Figure 2-20 and Figure 2-21 show contours of changes in groundwater elevation in model layers 1 and 5 caused by the demineralization wellfield. The smallest effect is for an extraction rate of 1,000 AFY from intermediate-depth wells at the Freitas-Bixby site (Figure 2-18). For that scenario, maximum drawdown at the center of the wellfield is 3 feet in layer 1 and slightly less than 3 feet in layer 5. Although the maximum drawdown is small, the cone of depression covers a large area. Water levels are lower by 1 foot or more throughout almost the entire San Juan Valley. Increasing annual extractions at the Freitas-Bixby site to 3,000 AFY and shifting the pumping to deep wells creates much more drawdown (Figure 2-19). Again, drawdown in layer 1 is similar to the drawdown in layer 5 and water levels are lower by 3 feet or more throughout almost the entire San Juan Valley.

There are subtle but informative differences between the Freitas-Bixby and Cagney Road sites. For the same annual extractions, maximum drawdown at the center of the wellfield is slightly greater at the Cagney Road site. For 1,000 AFY of pumping from intermediate depth wells, the Cagney Road site is projected to show a drawdown of 4 feet (versus 3 feet at the Freitas-Bixby site) and for 3,000 AFY of pumping from deep wells, the Cagney Road site is projected to show 8 feet of drawdown (versus 7 feet at the Freitas-Bixby site). This is due to the distance from the Cagney Road site to the San Benito River, which is the dominant head-dependent flow boundary in the system. As a result, water levels at the wellfield must fall farther to induce the same amount of additional seepage from the river. The greater distance from the San Benito River is partially offset by the shorter distance to San Juan Creek, which functions as a head-dependent boundary albeit on a smaller scale.

Figure 2-18: San Juan Valley Groundwater Elevation Changes - Run 54 [Freitas-Bixby; Intermediate-depth; 1,000 AFY]


A. Model Layer 1

B. Model Layer 5

Figure 2-19: San Juan Valley Groundwater Elevation Changes - Run 57 [Freitas-Bixby; Deep; 3,000 AFY]

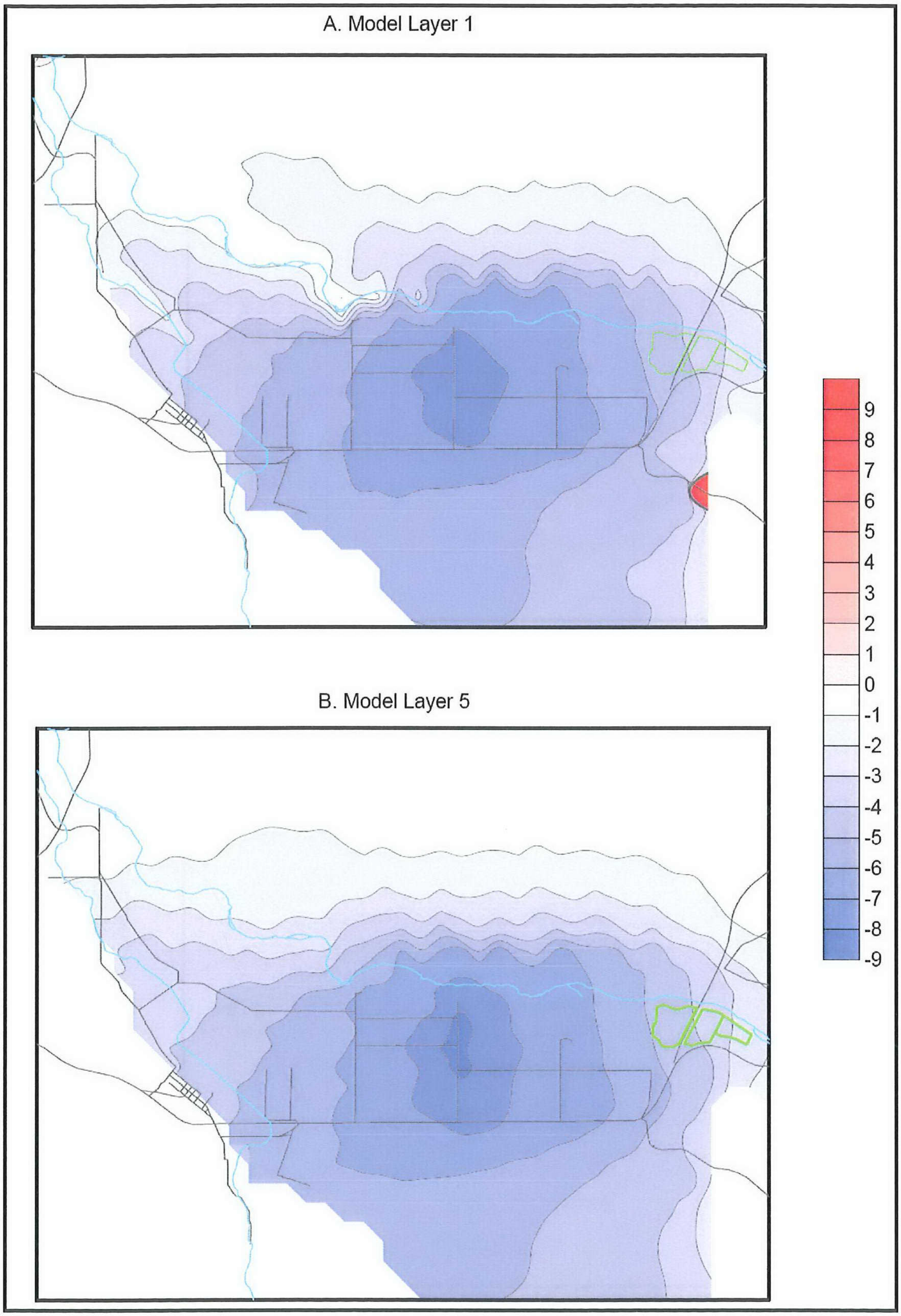


Figure 2-20: San Juan Valley Groundwater Elevation Changes - Run 58
[Cagney Road; Intermediate depth; 1,000 AFY]

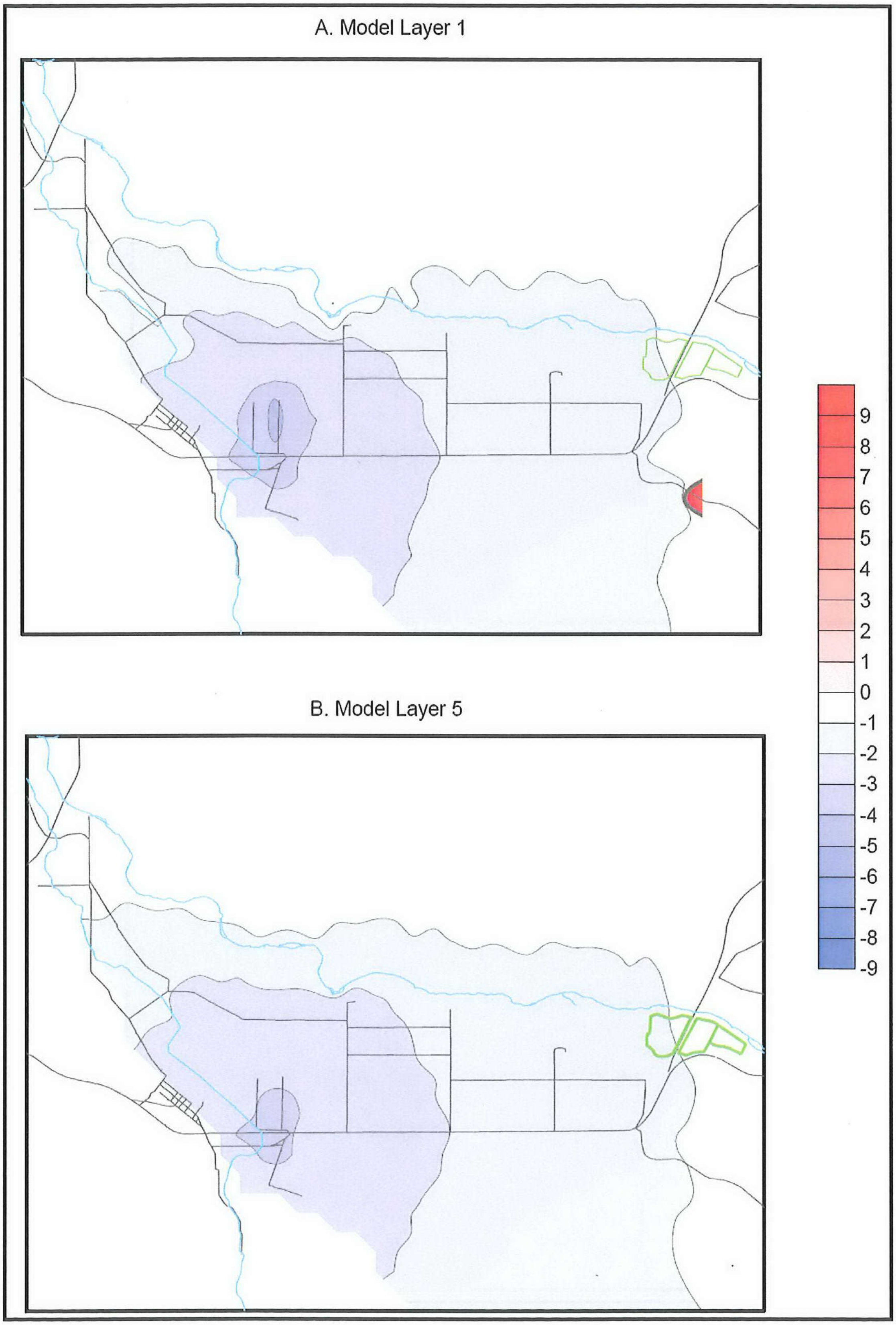
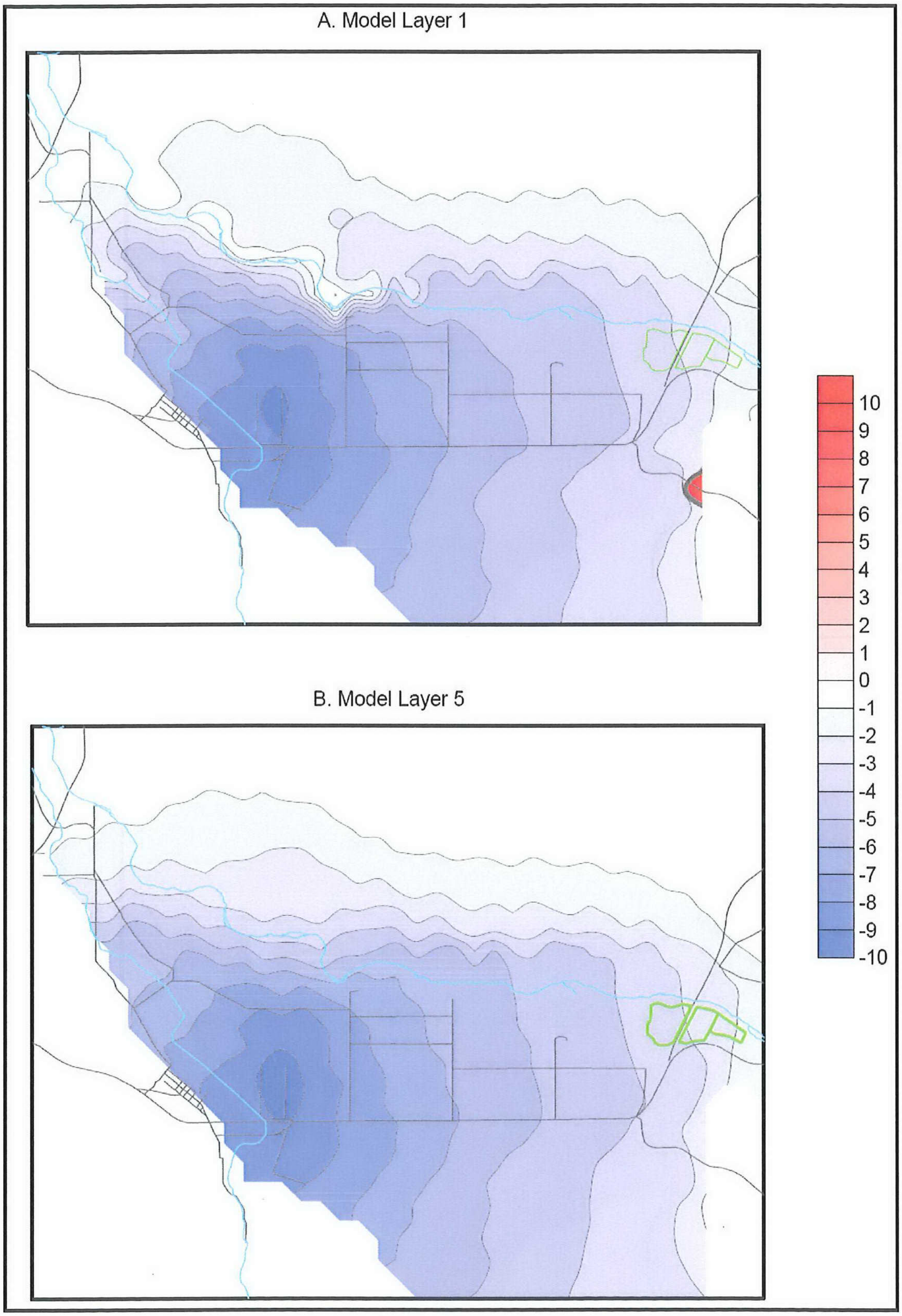


Figure 2-21: San Juan Valley Groundwater Elevation Changes - Run 61
[Cagney Road; Deep; 3,000 AFY]



2.6.5 San Juan Valley Groundwater TDS Changes

The impacts of 30 years of wellfield operation on groundwater salinity are shown in Figure 2-22, Figure 2-23, Figure 2-24, Figure 2-25 and Figure 2-26 . The salinity patterns are more complex than the water-level patterns because the largest changes tend to occur near steep salinity gradients that are often far from the wellfield. Although the regional water-level gradient still remains to the northwest in the wellfield scenarios, there are small shifts in flow rate and direction that cumulatively result in localized salinity differences relative to the reference simulation. The patterns are clearest in the two simulations with 3,000 AFY of production from deep wells (bottom graphs in Figure 2-25 and Figure 2-26). For both wellfield locations, layer 5 salinity tends to increase immediate upgradient of the wellfield. This appears to be the result of accelerating the movement of saltier water from the southeastern corner of the valley toward the wellfield. Conversely, salinity tends to decrease downgradient of the wellfield because relatively fresh groundwater from the northwestern portion of the valley is drawn toward the wellfield and saltier water arriving from the southeast is intercepted at the wellfield.

Changes in groundwater seepage to and from San Juan Creek and the San Benito River also cause long-term shifts in groundwater salinity along those waterways. A consistent effect of the wellfield, at either location, is to increase seepage from the river and decrease groundwater discharge into the river. The increase in seepage from the river occurs primarily along the eastern half of the valley and results in a slight decrease in local groundwater salinity (blue-shaded areas in the upper graphs of the figures). The decrease in groundwater discharge into the river occurs primarily along the western half of the valley. Two mechanisms could slightly increase local groundwater salinity along this reach. First, the increase in river percolation in the eastern half of the valley could diminish the flow available for percolation in the western half, thereby decreasing the diluting effect of river recharge on groundwater salinity. Second, the diminished river recharge during high flows could allow the wellfield to draw some of the saltier water presumed to be present north of the river channel into the river channel area, resulting in an increase in salinity relative to existing conditions. A similar phenomenon appears to occur along a reach of San Juan Creek near Anzar Road.

The use of intermediate-depth wells appear to minimize changes in deep (layer 5) groundwater salinity, including beneficial impacts. Figure 2-23 shows salinity maps for a desalination wellfield consisting of intermediate-depth wells at the Freitas-Bixby Site. TDS changes over 30-years of operation in layer 1 are identical to the changes when deep wells are used except in the immediate vicinity of Bixby Road, where a plume of low-salinity groundwater is drawn southward from the San Benito River channel. In model layer 5, the general pattern of salinity changes is the same as with deep wells, but the magnitude of the changes is reduced by as much as 100 mg/l. The blue zones representing decreases in layer 5 TDS concentrations shown in Figure 2-25 are potentially an erroneous feature of the model.

It should be noted that due to simplifying assumptions incorporated into the groundwater model, the solute transport component of the model is primarily useful for comparing relative differences among alternatives rather than predicting absolute TDS concentrations.

Figure 2-22: San Juan Valley Groundwater TDS Changes - Run 54 [Freitas-Bixby; Intermediate-depth; 1,000 AFY]

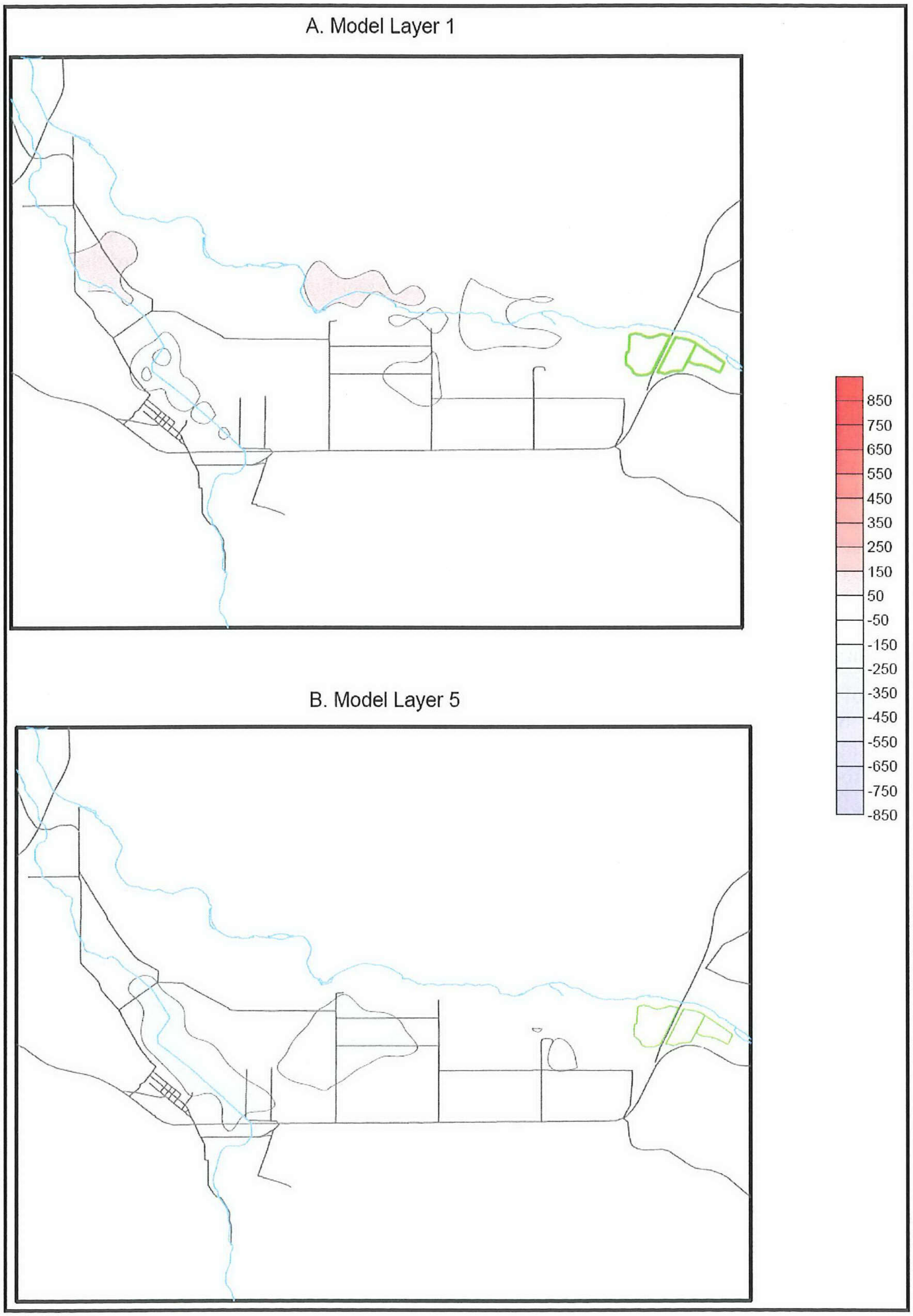


Figure 2-23: San Juan Valley Groundwater TDS Changes – Run 55 [Freitas-Bixby; Intermediate depth; 3,000 AFY]

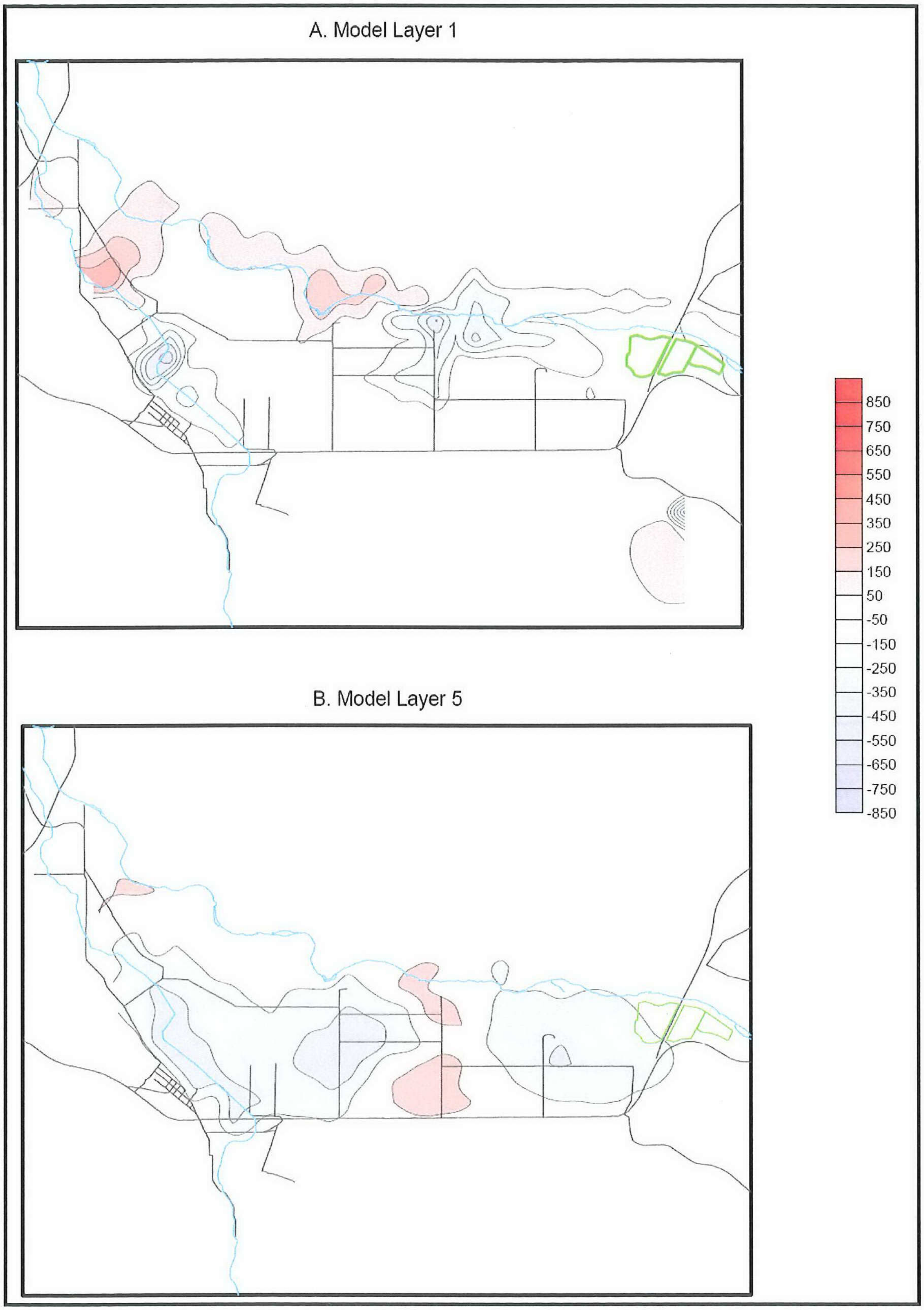
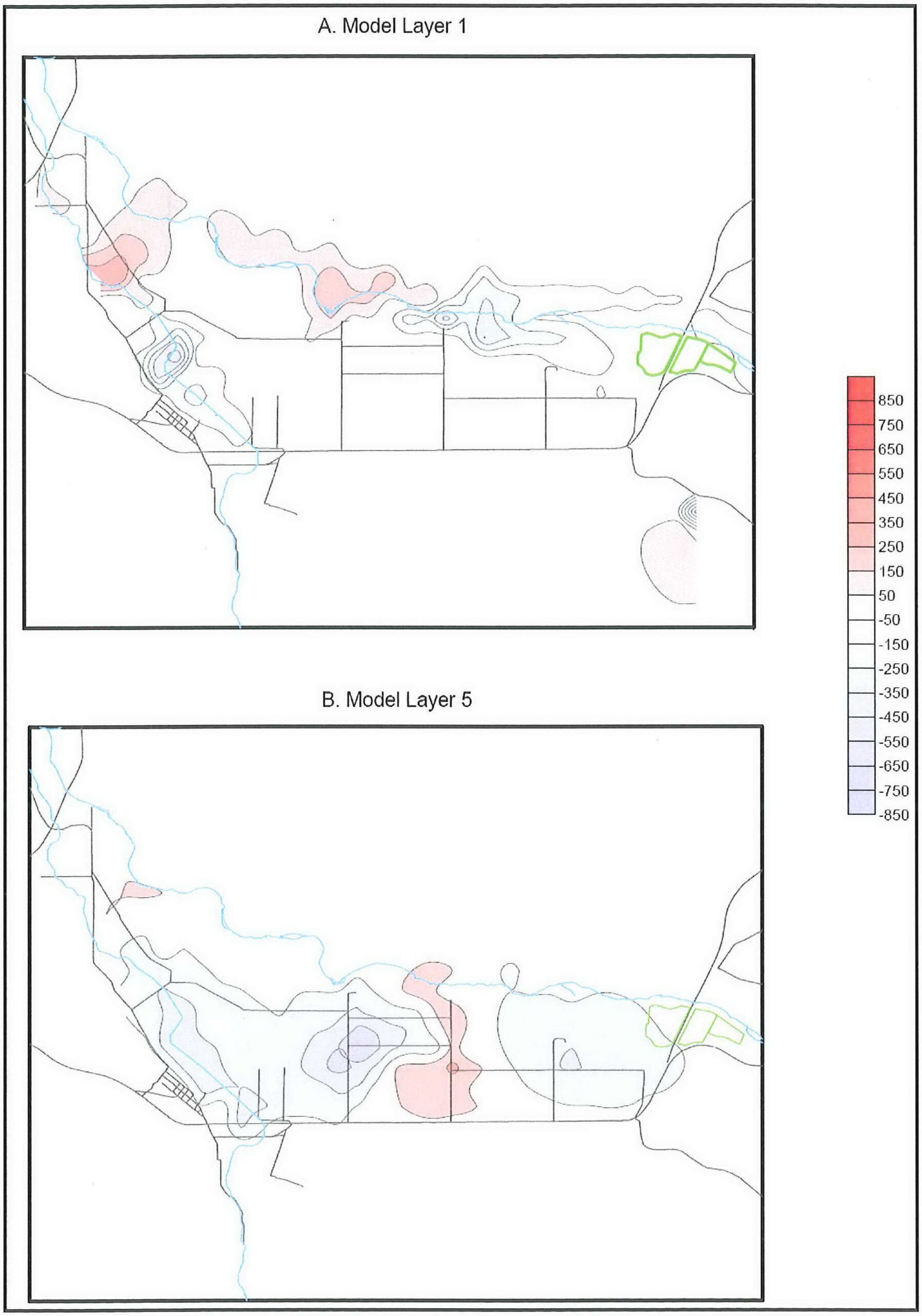


Figure 2-24: San Juan Valley Groundwater TDS Changes - Run 57
[Freitas-Bixby; Deep; 3,000 AFY]



A. Model Layer 1

B. Model Layer 5

Figure 2-25: San Juan Valley Groundwater TDS Changes - Run 58
[Cagney Road; Intermediate depth; 1,000 AFY]

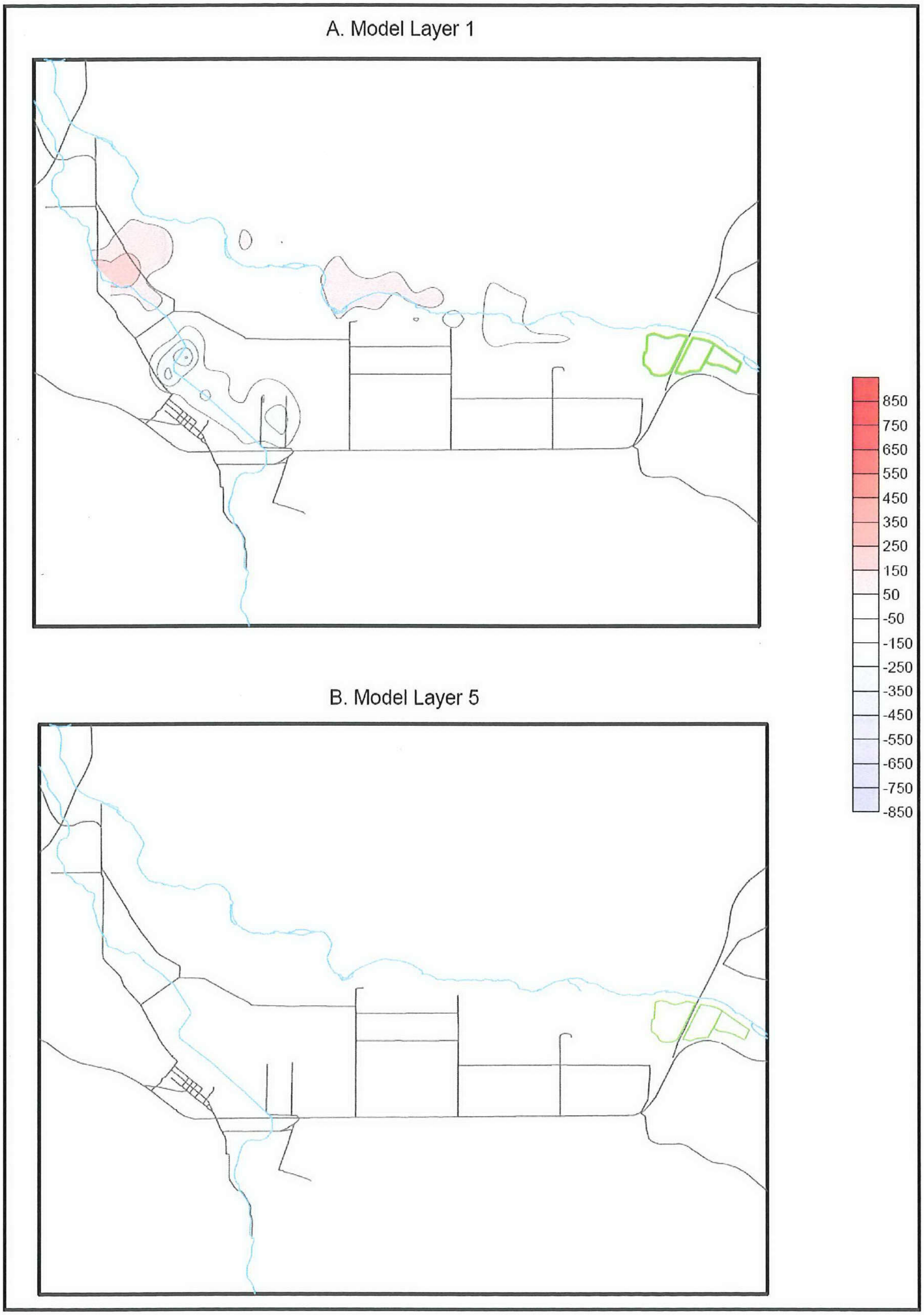
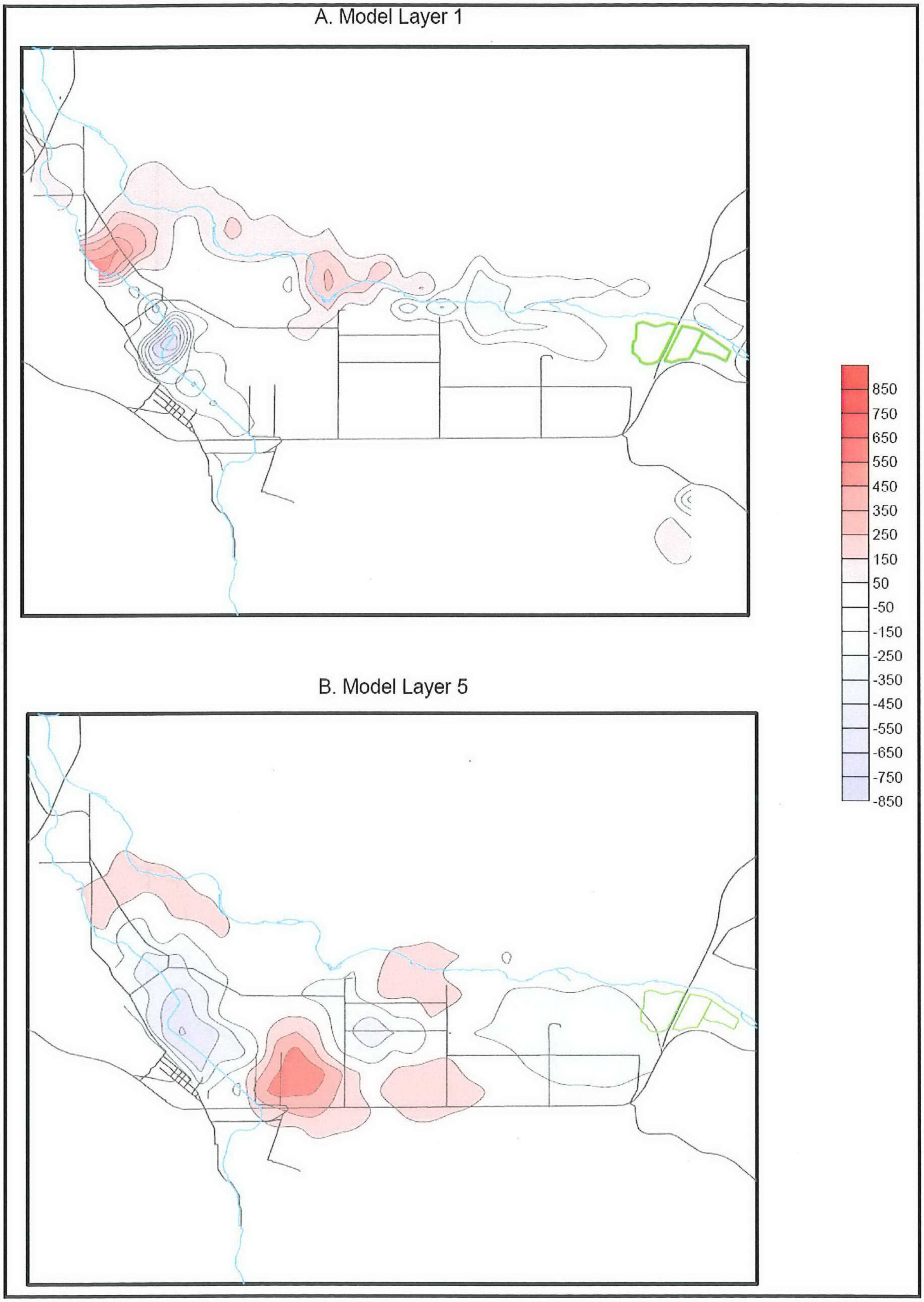


Figure 2-26: San Juan Valley Groundwater TDS Changes - Run 61
[Cagney Road; Deep; 3,000 AFY]



2.6.6 San Juan Valley Groundwater Budgets

Figure 2-27 and Figure 2-28 are bar charts showing the effect of wellfield operation on the groundwater budget of the San Juan Valley sub-basin. Figure 2-27 compares existing conditions with the wellfields operating intermediate-depth wells at 1,000 AFY and Figure 2-28 compares existing conditions with the wellfields operating at 3,000 AFY. The general patterns are essentially the same for both levels of production; the effects simply differ in magnitude. For this reason, the effects can be seen more clearly at the 3,000 AFY level of operation (Figure 2-28). Wellfield pumping appears as an increase in the length of the well outflow bar. At 3,000 AFY, the wellfield represents a 30% increase in total well production in the sub-basin. This increase is balanced by changes in three head-dependent flows in the groundwater system.

- Increased seepage from the San Benito River and San Juan Creek
- Decreased groundwater outflow to those waterways
- Increased groundwater inflow from the Hollister West sub-basin

Because of their locations, the two wellfield sites have slightly different effects on creek and river seepage. The Freitas-Bixby location is closer to the losing reach of the San Benito River and consequently has a slightly larger effect on seepage from the river and smaller effect on groundwater discharge to the river. Conversely, the Cagney Road site is closer to the gaining reach of the river and has the opposite relative effect on the two seepage flows. These differences are too small to be a practical consideration in wellfield siting.

Figure 2-27: San Juan Valley Groundwater Budgets - Run 54 and Run 58 (1,000 AFY)

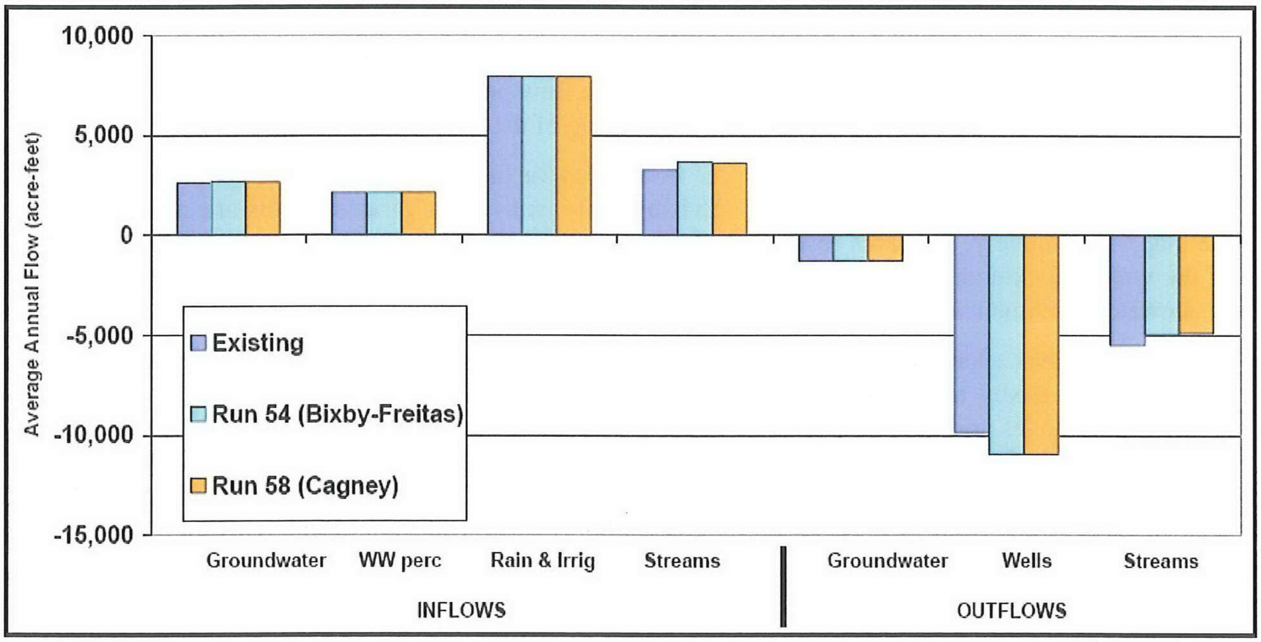
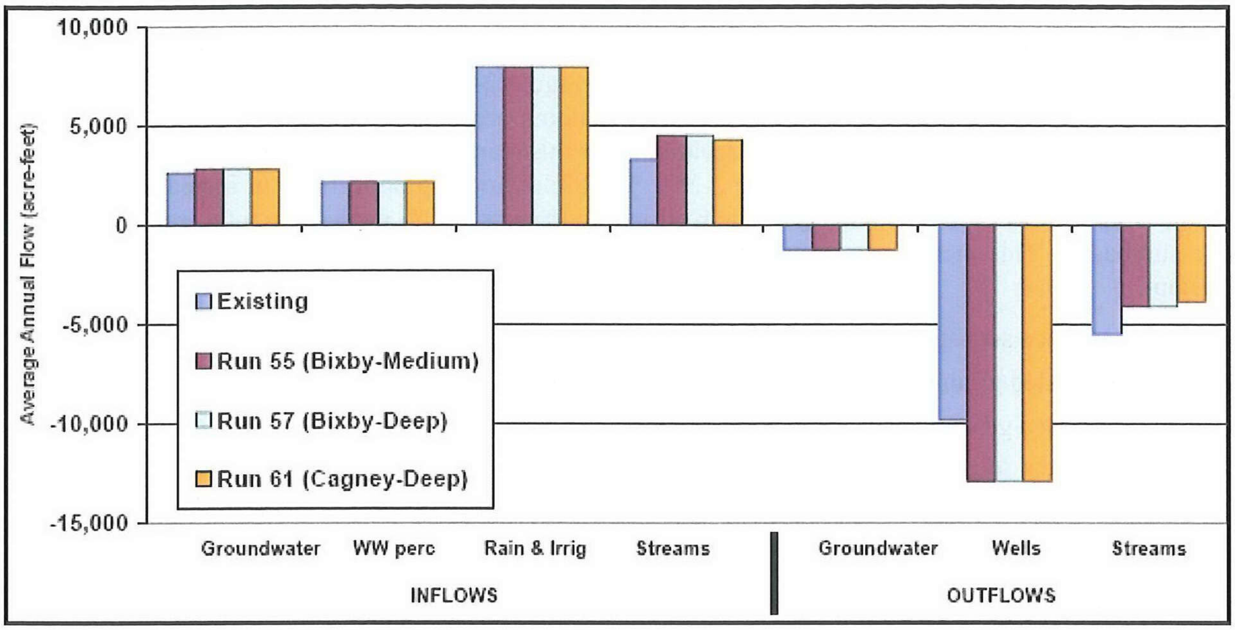


Figure 2-28: San Juan Valley Groundwater Budgets - Runs 55, 57 and 61 (3,000 AFY)



2.6.7 Groundwater Flow Paths

A groundwater flow path module (MODPATH) was run in conjunction with the groundwater model to reveal the source area and flow paths of water extracted by the wells. The flow paths are shown both by horizontal aggregation of all vertical flowpaths and by cross-sectioning of the basin along a single model grid column to show the vertical flow distribution. The flow paths were developed for three of the model runs (55, 57 and 61) to provide a representative sampling of the different conditions.

Figure 2-29 shows a plan view of the 30-year flow paths for the Freitas-Bixby site extracting 3,000 AFY using twelve intermediate-depth wells. The visible flow paths from various depths are superimposed on the map. Collectively, the paths reveal that the extracted water originates from an area east (upgradient) of the wellfield extending to the San Benito River and the west beds of the City of Hollister Domestic Wastewater Treatment Plant (DWTP).

Figure 2-30 shows a longitudinal cross-sectional profile of the flow paths along a line extending from the intersection of Bixby and Freitas Roads through the intersection of Highway 156 and the San Benito River (along model grid column 51). The intermediate-depth wells capture most of the deep percolation from shallow aquifers as far upgradient as the DWTP. Groundwater from layers 3 and 4 is drawn upward to the extraction wells in layers 1 and 2. In contrast, flow paths in layer 5 appear to be more isolated from shallow zones. The deep flow paths are relatively short due to lower contributions from layer 5 and the origins of these flow paths only extend up to layer 4.

Figure 2-31 shows a view of the 30-year horizontal flow paths for the Freitas-Bixby site extracting 3,000 AFY using six deep wells. In plan view, the source area is almost identical to the source area for the intermediate-depth option. The vertical profiles of the flow paths are noticeably different, however, as shown in Figure 2-32. The flow paths for model layers 3 to 5 are relatively long due to the screened depth of the extraction wells. The profiles reveal that the flow paths ultimately originate at or near the ground surface. For layers 3 and 4, flow originates from recharge between about Flint Road and the west percolation beds of the DWTP. For layer 5, the flow paths originate from layers 2 and 3 below the DWTP and river, although a longer simulation would probably reveal that some of the flow paths extend to one of those surface water bodies or the ground surface beyond the river.

The travel time from the DWTP to the Freitas-Bixby wellfield was approximately 25 years. This represents an average time that does not fully account for variability of individual flow paths in groundwater systems, which typically are log-normally distributed. Thus, some water originating near the DWTP could arrive in much less than 25 years, but it would be a small percentage of the overall flow.

The particle traces terminate wherever they intersect the ground surface, even if that is much sooner than 30 years. Deeper model layers have larger collection areas due to the long time required to terminate at the ground surface. The traces in the cross section plot show that flow paths in model layer 1 do not extend more than approximately 1,000 feet from the well, almost all of the layer 2 traces extend less than 5,000 feet upgradient of the well, traces for layers 3 and 4 reach the ground surface 5,000 to 10,000 feet upgradient and traces for layer 5 reach the ground surface more than 10,000 feet upgradient of the well.

The deeper flow paths for layer 5 do not mean that groundwater in that layer is isolated from shallow layers, but rather that the connection with shallow layers is farther upgradient and the travel time is longer. This would be a benefit only if the following conditions were true:

- Water supply wells produced only from layer 5. In reality, existing wells are all screened over multiple model layers, typically layers 2 thru 5 and at a minimum layers 4 and 5. So even if layer 5 water quality were improved, higher salinity shallow groundwater would still reach the wells via the screened intervals in layers 2 thru 4. This would result in a benefit to salt management in this groundwater basin.
- Intermediate-depth wells could increase river recharge relative to deep percolation of rainfall and irrigation water below fields. In reality, the water budget results for the two simulations are essentially identical (see Figure 2-28). The budgets for intermediate-depth and deep wells at the Freitas-Bixby site are almost exactly the same. This means that the ultimate sources of water to a demineralization wellfield along Bixby Road are the same regardless of well depth.

These simulation results do not present a compelling case for using intermediate-depth rather than deep wells for the demineralization wellfield. The differences in water levels, flow paths, water budgets and long-term salinity patterns are minor. A wellfield consisting of intermediate-depth wells would be more expensive to construct, largely because of the increased number of well pumps and electrical control panels that would need to be installed and would not provide a substantial benefit to long-term changes in groundwater TDS concentrations.

To compare the flow path results for the Freitas-Bixby site to the Cagney Road site, a capture zone analysis was completed for the deep well option at the Freitas-Bixby site. The intermediate-depth well option was not evaluated based on the results from the Freitas-Bixby analysis. Figure 2-33 and Figure 2-34 show the horizontal and vertical flow paths for a set of six deep wells at the Cagney Road site extracting 3,000 AFY from the groundwater basin. The basic assumptions were the same as for the Freitas-Bixby site with respect to number of wells (six), well spacing (600 feet), pumping volume (3,000 AFY) and screened layers (3 through 5).

The horizontal and vertical trace patterns are similar to those for the Freitas-Bixby location and extend approximately 10,000 feet due east from the wellfield, spreading slightly toward the eastern end. The profiles differ from the Freitas-Bixby location in that the flow paths for model layers 4 and 5 bend only slightly upward in the upgradient direction. This suggests that the connection with the land surface is farther upgradient, probably near the DWTP and San Benito River. Water reaching wells at this location would, on average, have a longer subsurface travel time than water reaching wells at the Freitas-Bixby location. The rate of travel is fairly constant along individual particle traces, with some scatter among the traces. The average velocity in the deep layers is approximately 330 feet per year. As explained above, these traces do not fully account for heterogeneity in aquifer characteristics and preferred flow paths. A small percentage of the water would travel considerably faster than the average velocity.

Figure 2-29: Horizontal Flow Paths – Run 55
[Freitas-Bixby; Intermediate depth; 3,000 AFY]

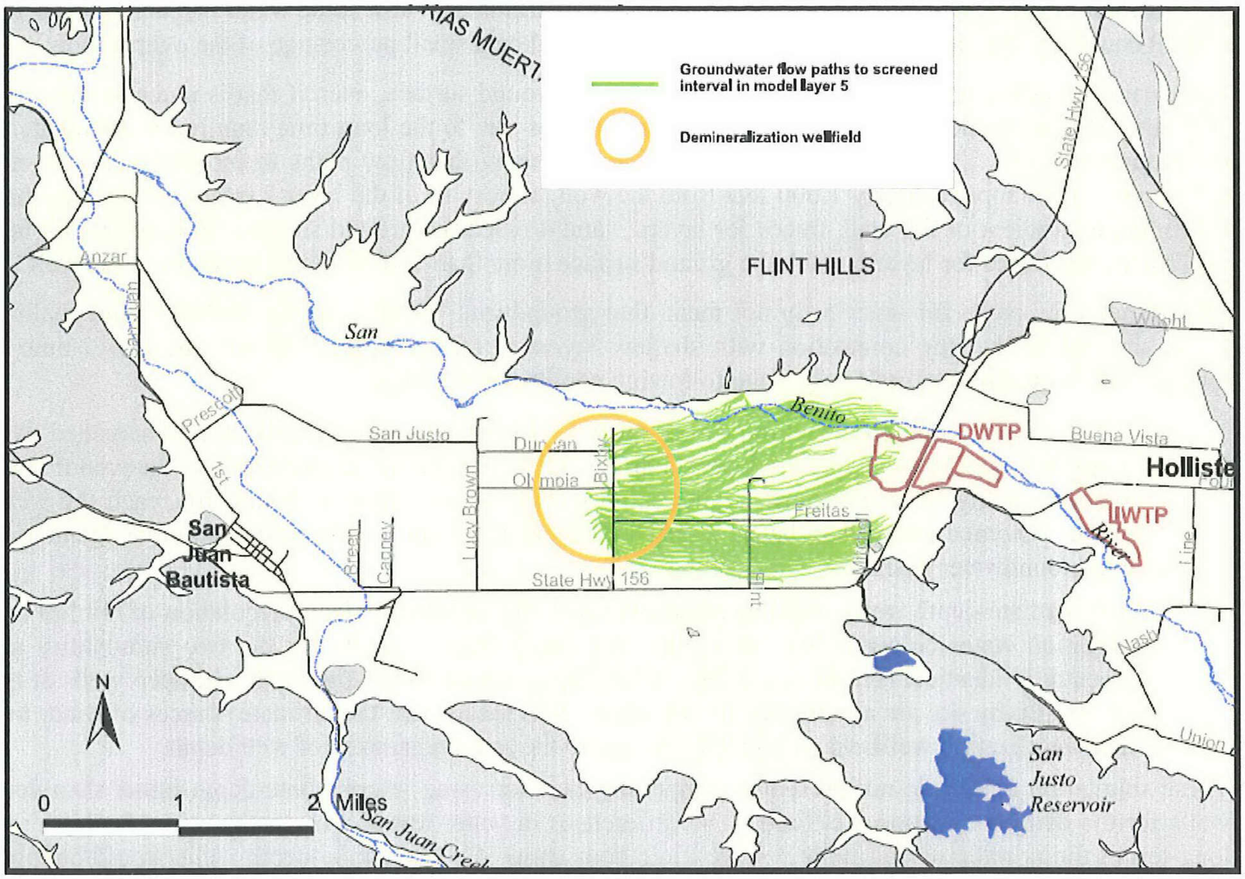


Figure 2-30: Vertical Flow Paths – Run 55
[Freitas-Bixby; Intermediate depth; 3,000 AFY]

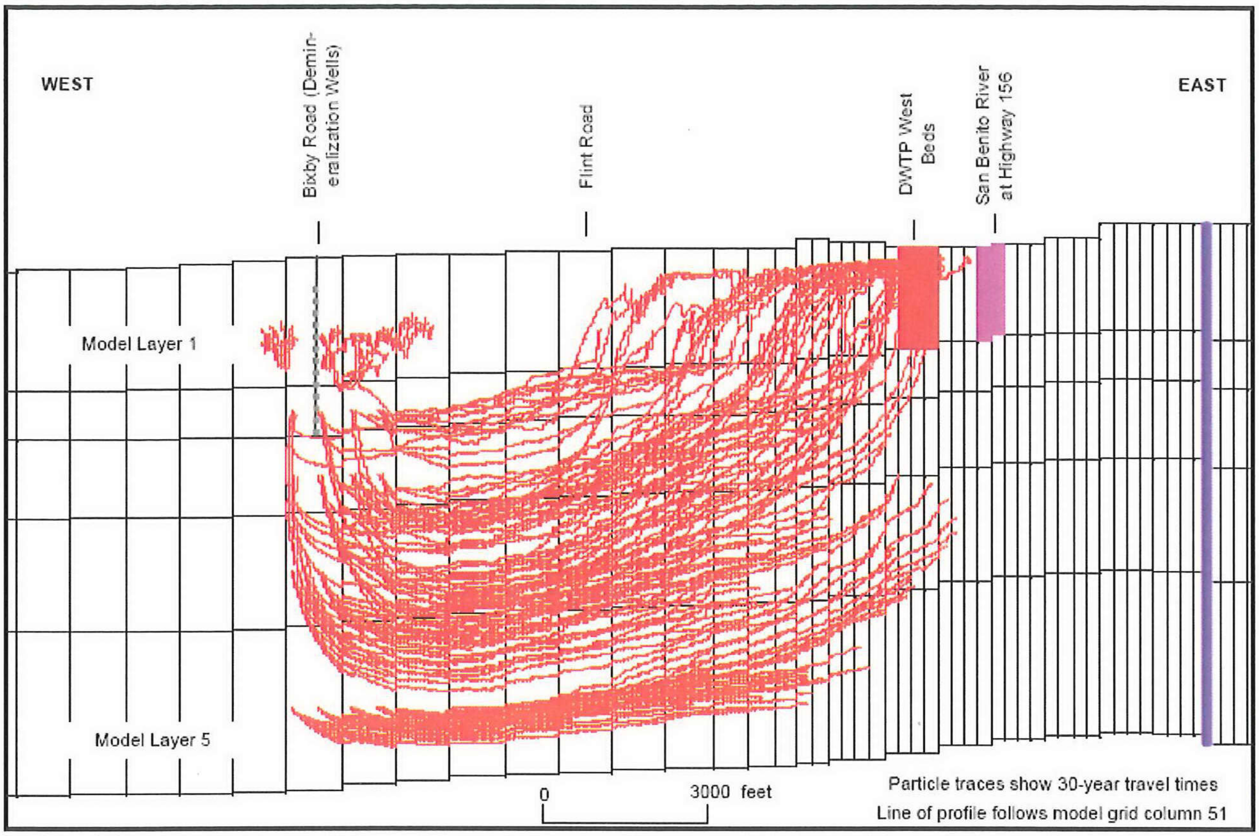

WEST
Bixby Road (Demin-eralization Wells)
Flint Road
DWTP West Beds
San Benito River at Highway 156
EAST
Model Layer 1
Model Layer 5
0
3000 feet
Particle traces show 30-year travel times
Line of profile follows model grid column 51

Figure 2-31: Horizontal Flow Paths – Run 57
[Freitas-Bixby; Deep; 3,000 AFY]

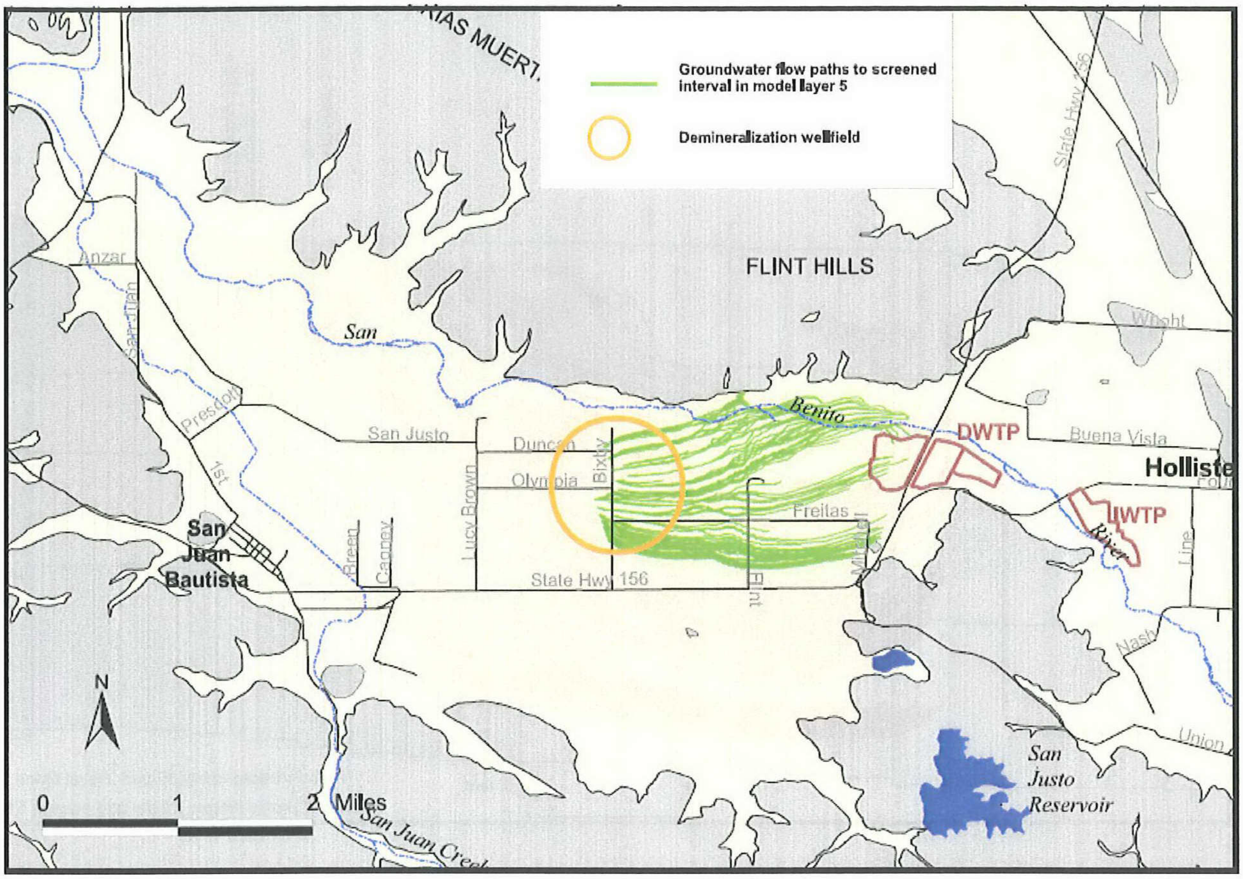


Figure 2-32: Vertical Flow Paths – Run 57 [Freitas-Bixby; Deep; 3,000 AFY]

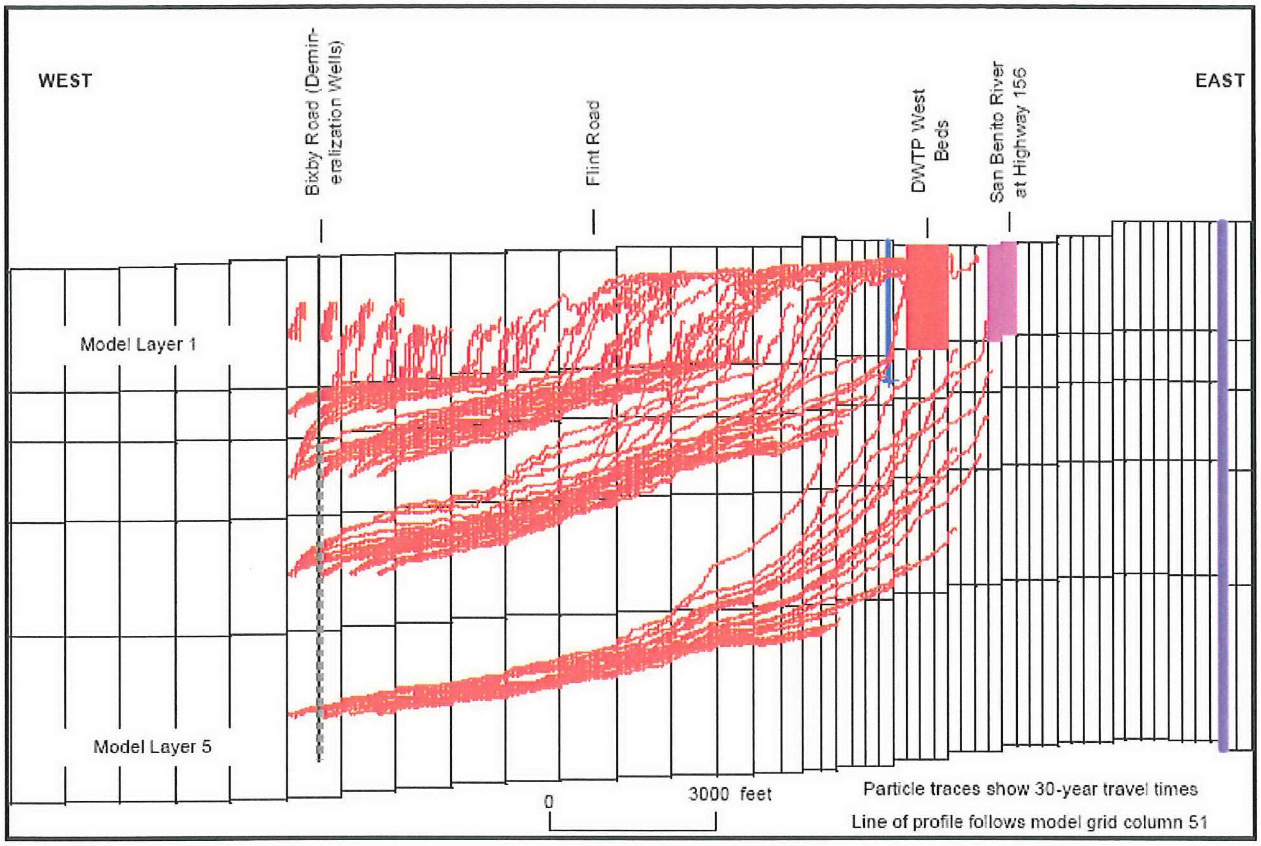


Figure 2-33: Horizontal Flow Paths – Run 61
[Cagney Road; Deep; 3,000 AFY]

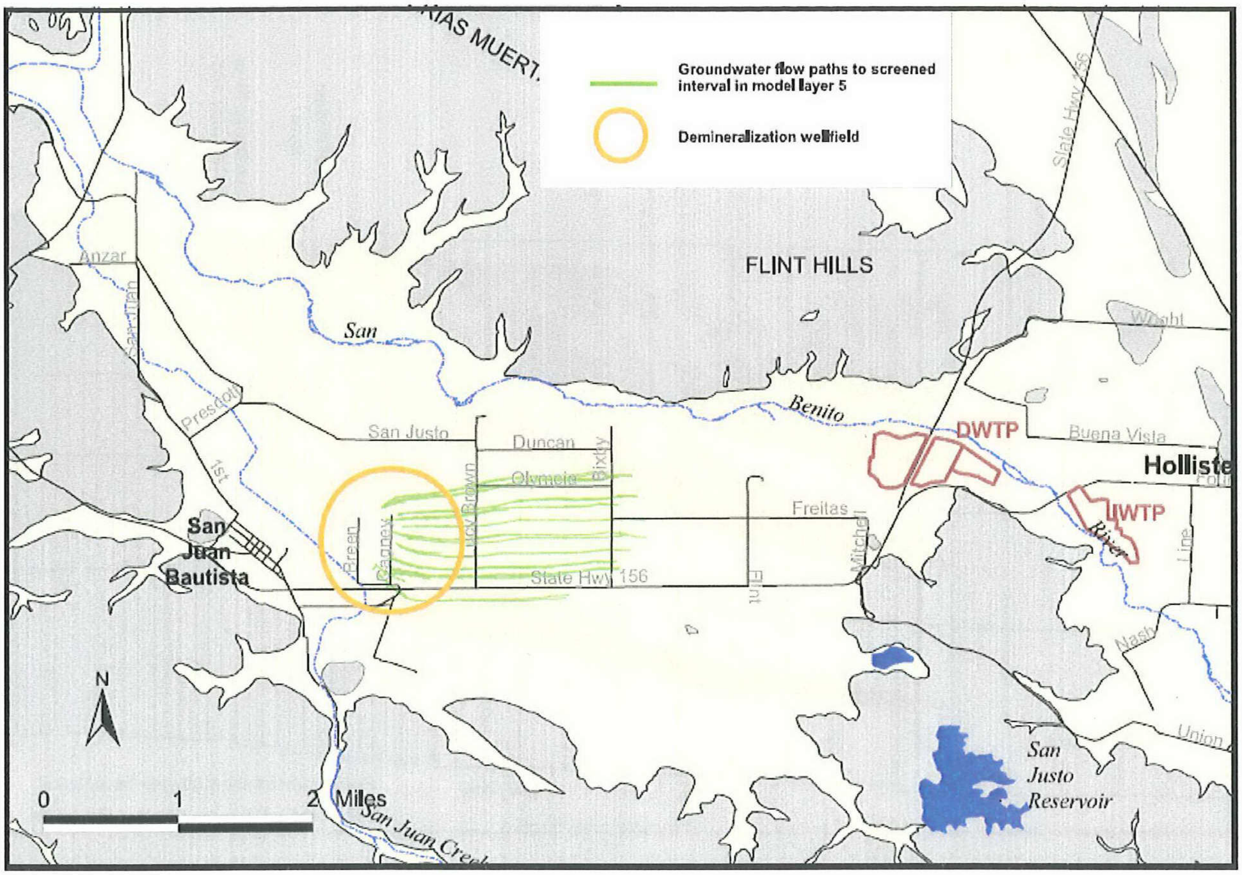
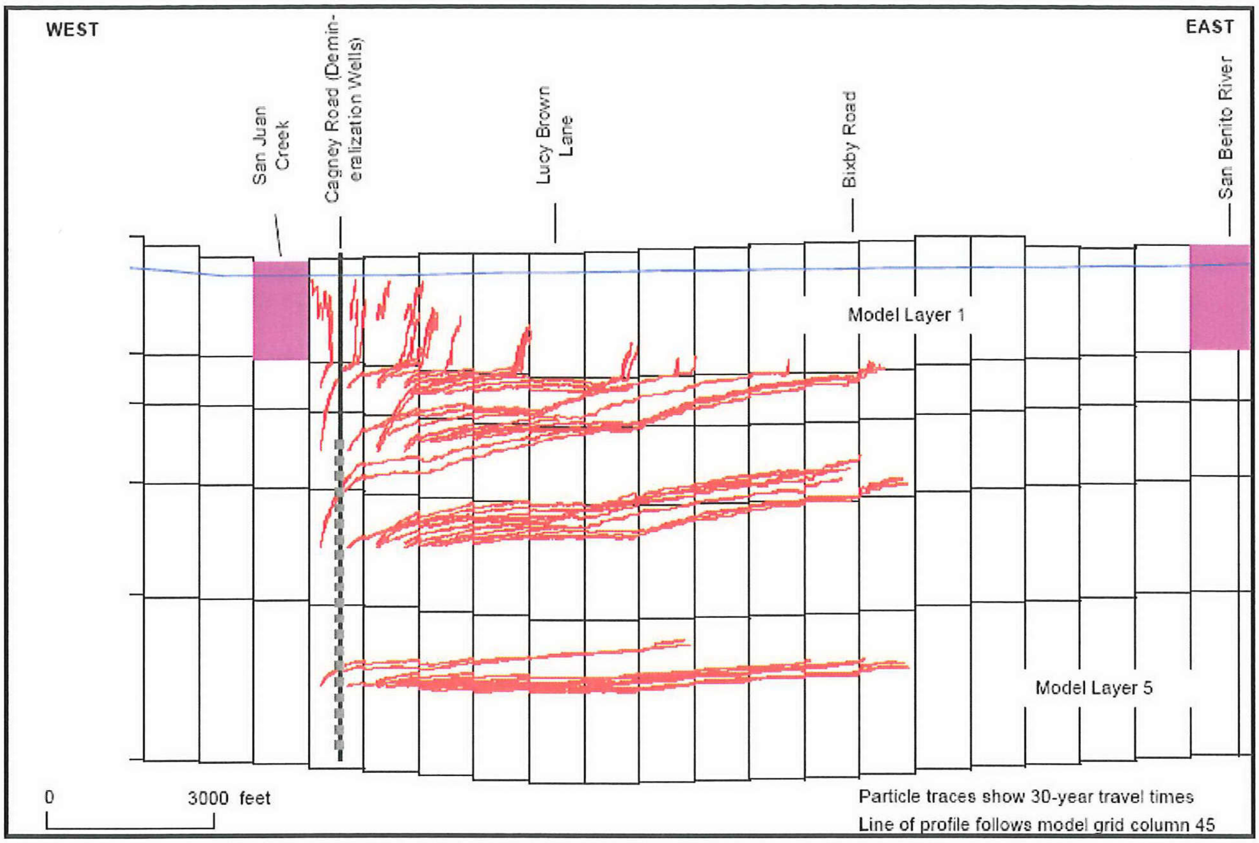


Figure 2-34: Vertical Flow Paths – Run 61
[Cagney Road; Deep; 3,000 AFY]


WEST
EAST
San Juan Creek
Cagney Road (Demin-eralization Wells)
Lucy Brown Lane
Bixby Road
San Benito River
Model Layer 1
Model Layer 5
0
3000 feet
Particle traces show 30-year travel times
Line of profile follows model grid column 45

2.6.8 Preliminary Conclusions

The following conclusions can reasonably be drawn from these preliminary results:

Groundwater Levels

- The 3,000 AFY level of production provides greater water-level benefits than the 1,000 AFY alternative.
- The beneficial effects of lowered water levels cover a large portion of the San Juan Valley regardless of the wellfield location, although the largest effects are close to the wellfield.
- The maximum drawdown relative to existing conditions at a 3,000 AFY level of production is modest relative to water level fluctuations associated with droughts and wet periods, and the minimum water levels during droughts would still be substantially higher than historical water levels prior to importation of CVP water.
- If future recycling of wastewater for irrigation decreases agricultural groundwater use in the sub-basin, pumping at the demineralization wells could be increased to offset that change and prevent shallow groundwater problems from worsening.
- There is little difference in water-level effects in the use of intermediate-depth versus deep wells.

Sub-Basin Groundwater Balance

- The water balance of the San Juan sub-basin can absorb at least 3,000 AFY of additional pumping without causing overdraft.

- Even at 3,000 AFY of groundwater extractions, there is still outflow from the sub-basin via discharge to the San Juan Creek, the San Benito River and the Pajaro River.
- Additional modeling to assess the ability of the groundwater basin to provide increased levels of groundwater for potable water uses is planned to determine if a larger demineralization facility could be constructed to serve more potable water to the identified service area.

Groundwater Salinity

- The primary effects on groundwater salinity are related to increased river seepage in the eastern half of the valley and small horizontal shifts in salinity contours. These resulting contours should be interpreted qualitatively due to limited data to support the model results. This is particularly true for the locations where the groundwater model predicted the largest impacts to groundwater salinity.

Wellfield Location

- The Cagney Road and Freitas-Bixby sites generally produce similar results, so either would be acceptable as a groundwater demineralization supply location. The Cagney Road site might be preferable because the water-level benefits would be focused in an area where they are most needed.
- The results suggest a possible new wellfield location with potential beneficial characteristics. This location is adjacent to Highway 156 between Lucy Brown Lane and Bixby Road. This site is further studied in the following section.

2.7 Highway 156 Site Analysis

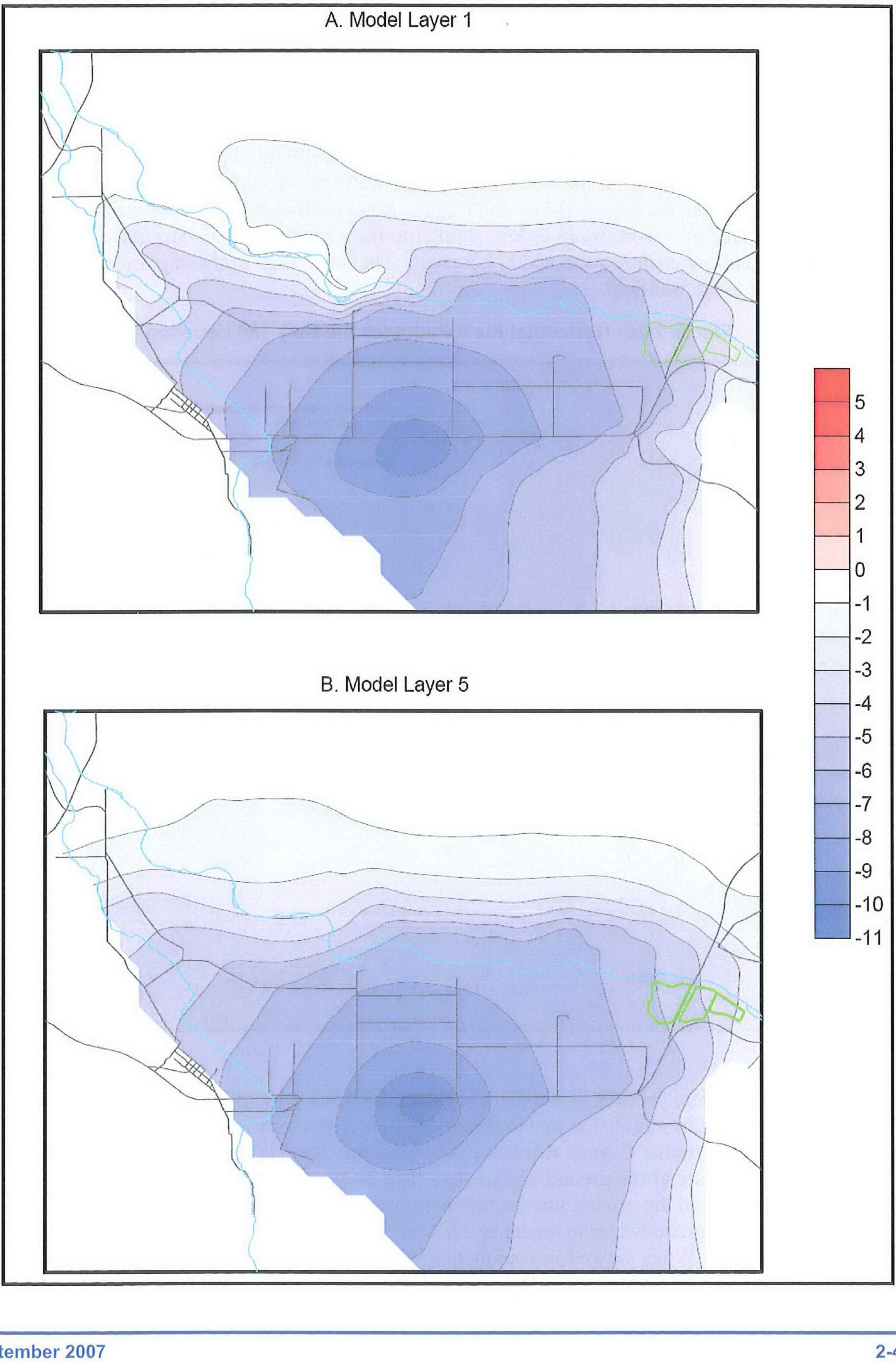
Given the apparent existing TDS gradient from relatively high concentrations in the southeastern part of the San Juan Valley to relatively low concentrations toward the northwestern end, a wellfield adjacent to Highway 156 between Lucy Brown Lane and Bixby Road could intercept high TDS water before it migrates to the north and west. Any possible increases in groundwater salinity immediately upgradient of the wellfield, a pattern evident in the Freitas-Bixby and Cagney Road simulations, would be in an area where there are few existing wells. This would minimize any potential negative salinity impacts on groundwater users. The main benefits of this location are:

- High existing groundwater salinity (overall salt management benefits)
- Few existing wells (minimization of well interference)
- It effectively lowers water levels in the area west of Lucy Brown Lane where existing water levels are high (water level benefits)
- Upgradient salinity increases would be in an area with few wells (minimization of existing well impacts)

A simulation was completed to investigate this new location. Six deep wells spaced 600 feet apart were added to the model along Highway 156 between Lucy Brown Lane and Bixby Road. Annual production was 3,000 AFY and extraction was from model layers 3 thru 5. Land use, water use and wastewater percolation remained at existing levels throughout the 30-year simulation.

Figure 2-35 shows contours of groundwater elevation changes resulting from operation of the Highway 156 wellfield. The water-level impact increases during the first few years of operation then reaches an equilibrium state. The fully-equilibrated changes are shown in Figure 2-35.

Figure 2-35: San Juan Valley Groundwater Elevation Changes – Hwy 156 Location [Highway 156; Deep; 3,000 AFY]



Groundwater elevations would decrease by approximately 8 feet near the wellfield and 2 or more feet throughout the San Juan sub-basin between Mitchell Road and Anzar Road. The area with the most severe existing shallow groundwater problems is between Cagney Road and Anzar Road where groundwater levels would be lowered by 3 to 5 feet. The change in water levels is nearly the same for model layers 1 and 5. This again demonstrates that the pumping from deep wells does not noticeably alter vertical water-level gradients in the sub-basin.

Horizontal flow paths identifying the 30-year capture zone of the wellfield are shown in Figure 2-36. The capture zone is the area from which groundwater flows to the wellfield, which for this location extends approximately two miles east from the eastern end of the wellfield, the upgradient direction for regional groundwater flow. Unlike the Freitas-Bixby and Cagney Road wellfields, the row of wells at this site was assumed to be oriented east-west, more or less parallel to the regional groundwater flow direction. This did not result in a narrow capture zone width, however. The outer edge of the capture zone represents a 30-year travel time to the wellfield.

Figure 2-36: Horizontal Flow Paths for the Hwy 156 Location

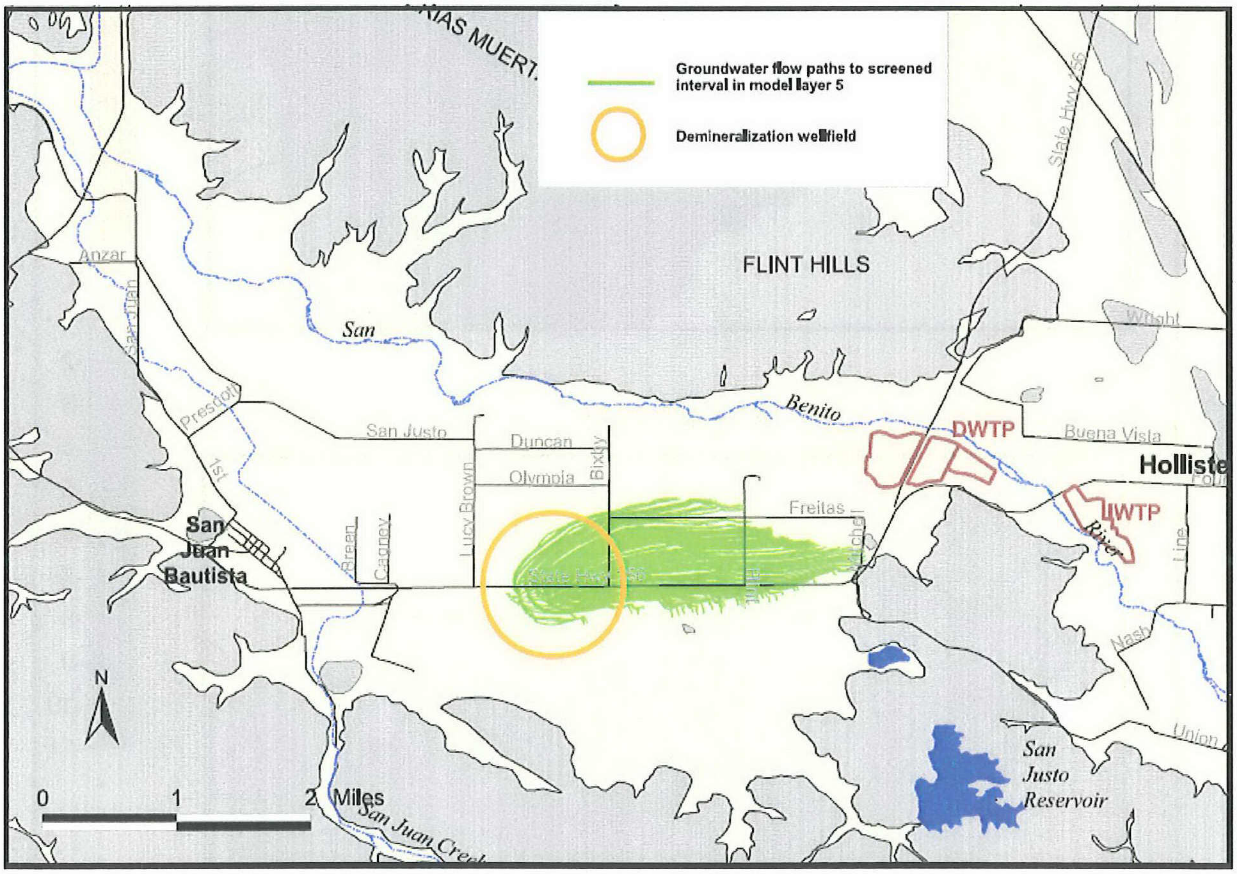
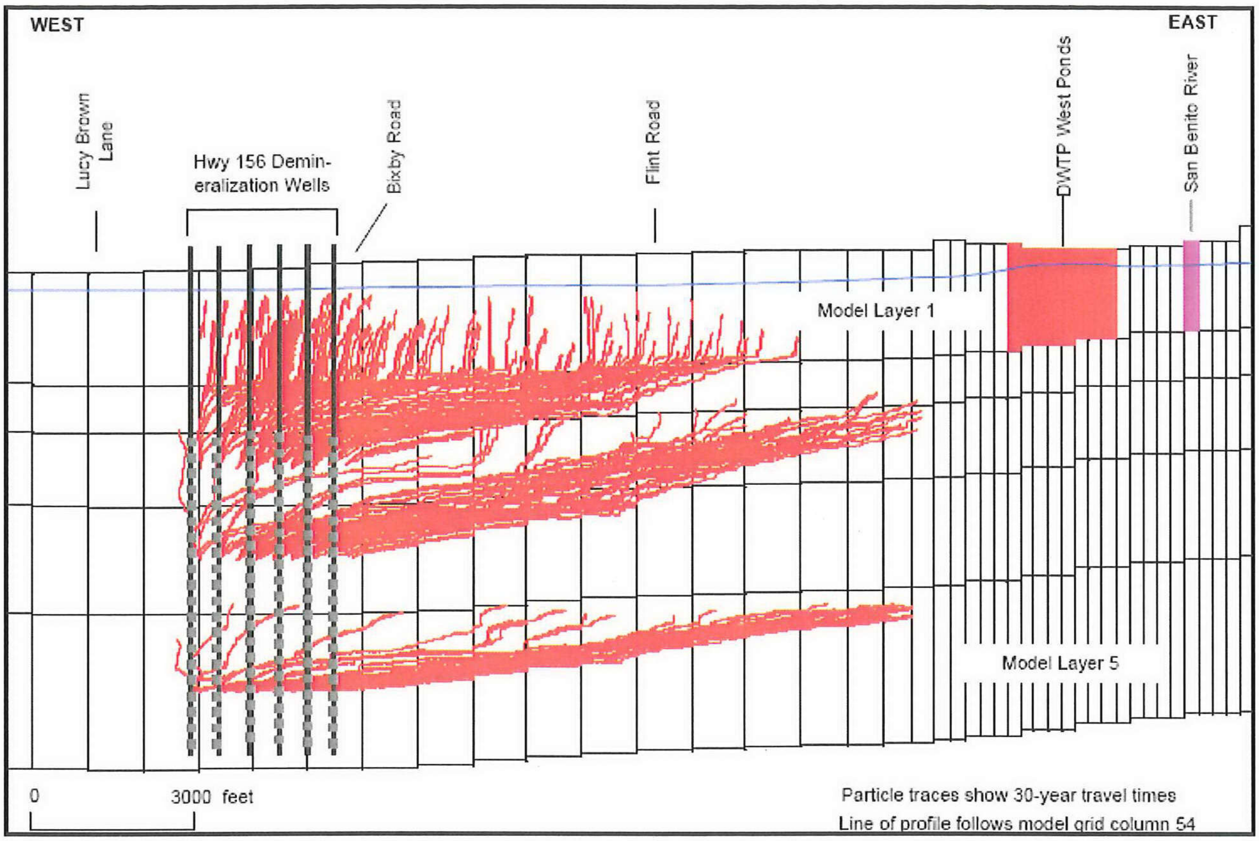


Figure 2-37 shows vertical profiles of the particle traces for this wellfield location. A larger number of particles were used for this simulation due to the orientation of the wellfield. The flow path patterns are very similar to the ones for the Cagney Road wellfield location. Particle traces arriving at the wellfield in model layers 1-3 originate at the ground surface less than 30 years prior to reaching the wellfield. The distance and travel time to the ground intersection point ranges fairly continuously from 0 to 2 miles. In contrast, flow paths for groundwater in model layers 4 and 5 are deep in the subsurface throughout the 30-year simulation period. When viewed in conjunction with the flow paths for the Bixby-Freitas wellfield site (see Figure 2-32), it appears likely that the deep flow paths would eventually approach the ground surface near the DWTP and the adjacent reach of the San Benito River.

Figure 2-37: Vertical Flow Paths for Hwy 156 Wellfield
[Highway 156; Deep; 3,000 AFY]



Particle traces show 30-year travel times
Line of profile follows model grid column 54

The impact of the Highway 156 wellfield on the sub-basin groundwater budget is essentially the same as for the other locations, as shown in Figure 2-38. The increase in groundwater extraction from the current conditions is balanced approximately equally by increases in percolation from the San Benito River (upstream of Bixby Road) and decreases in groundwater discharge to the San Juan Creek and the San Benito River (downstream of Bixby Road). Minor differences between the Highway 156 water budget and the other water budgets may be caused by model recalibration work and updating of the baseline simulation that was completed between execution of the Freitas-Bixby/Cagney Road simulations and the Highway 156 simulation.

Figure 2-38: Groundwater Budget Comparison for Hwy 156 Location
[Highway 156; Deep; 3,000 AFY]

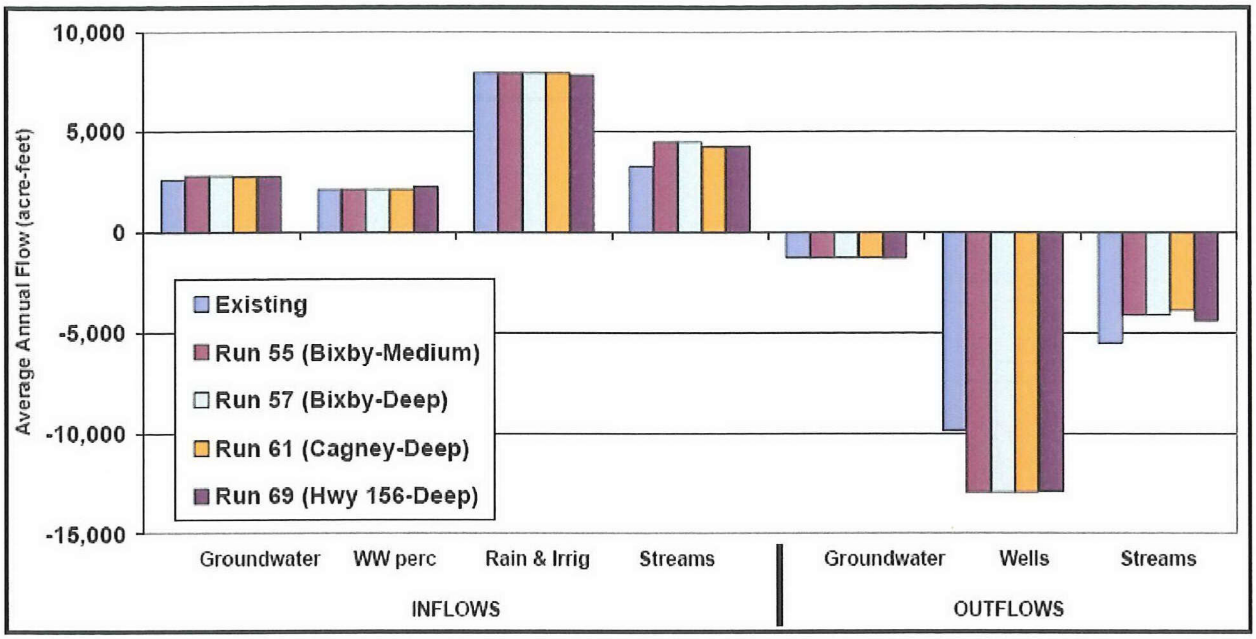
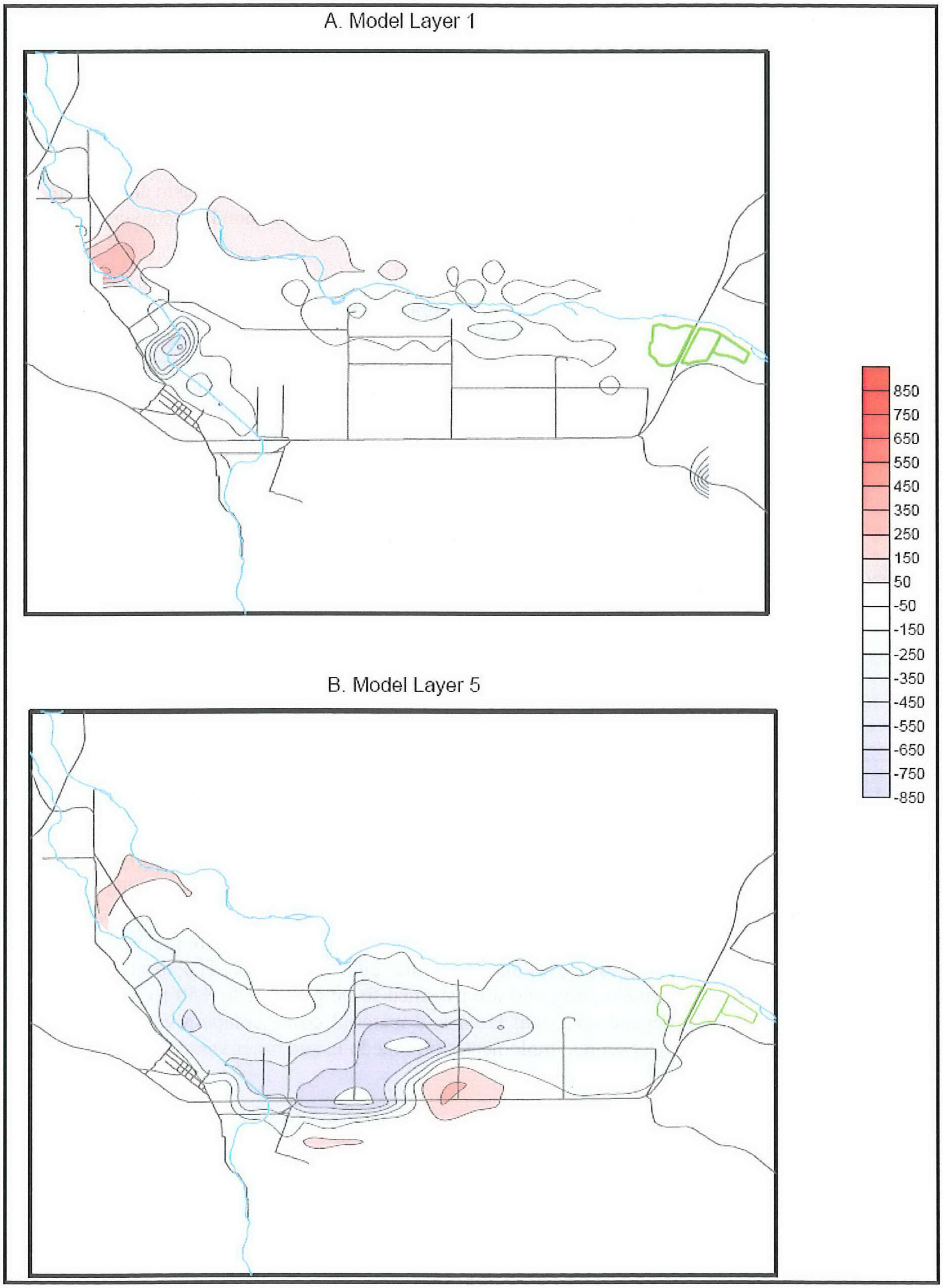


Figure 2-39 shows the effect of the Highway 156 wellfield on groundwater salinity in model layers 1 (shallow) and 5 (deep). Changes in layer 1 salinity are very similar to the changes for the other wellfield locations and all result from shifts in the locations and amounts of percolation to and from streams. Increases and decreases of up to approximately 400 mg/l occurred at several locations. As expected, there was a slight increase in groundwater salinity in model layer 5 immediately upgradient of the wellfield (lower graph of Figure 2-39). This is because the wellfield accelerates the flow of groundwater from the southeast, where ambient TDS concentrations are relatively high. The maximum increase of approximately 250 mg/l was near the intersection of Bixby Road and Highway 156. A few domestic water supply wells with relatively small extractions are located within a half-mile of the intersection so overall impacts to existing well operations would be minimal.

It should be noted that due to simplifying assumptions incorporated into the groundwater model, the solute transport component of the model is primarily useful for comparing relative differences among alternatives rather than predicting absolute TDS concentrations.

Figure 2-39: San Juan Valley Groundwater TDS Changes for Hwy 156 Location [Highway 156; Deep; 3,000 AFY]



2.8 Groundwater Extraction Project Recommendations

Based on continued modeling of the groundwater basin performed as part of the Hollister Urban Area Water and Wastewater Master Plan (HUAWWMP), it has been determined that withdrawals of groundwater from the San Juan Basin to produce 3,000 AFY of potable water do not return the basin to overdraft conditions. For treatment system water recoveries[4] ranging from 75% to 98%, this would result in total pumping increases of 3,050 AFY to 3,860 AFY. As total pumping approaches 3,860 AFY, the basin becomes more susceptible to a return to overdraft conditions. This limitation provides one impetus to implement a demineralization system that recovers as much of the influent water as possible. Higher recovery rates increase the utility of each unit of groundwater extracted from the basin and require smaller investments in waste stream management facilities. The specific recommended recovery rates will be evaluated in the following sections of this Study.

To be consistent with the HUAWWMP, where the San Juan Valley demineralization project has been recommended for implementation, a potable water supply of 3,000 AFY will be used as the basis for development of the treatment, waste disposal and distribution portions of this Feasibility Study. The wellfield would consist of between 6 and 8 deep wells spaced 600 feet apart, each with an instantaneous capacity of 500 gpm and, with a 16-hour daily operational period, an annual yield of 540 AFY. For a reverse osmosis system water recovery of 83%[5], the facilities summarized in Table 2-5 are required for the groundwater extraction and conveyance aspects of the demineralization facility. Based on recent groundwater sampling in the San Juan Valley, a groundwater TDS of 1,800 mg/L is used as the basis of analysis for the treatment and waste concentrate disposal systems.

Table 2-5: Groundwater Extraction & Conveyance Facilities [a]

Facility	Size or Capacity
Groundwater Wells	7 deep wells (500 gpm & 540 AFY each)
Groundwater Well Pumps	7 pumps at 500 gpm, 25 HP each
Connecting Piping	14" diameter; 3,600 lineal feet (LF)
Conveyance Piping	18" diameter; 2,640 LF
Treatment Facility Location [b]	Within ½ mile of wellfield

Notes:
a – Based on 83% recovery via reverse osmosis
a – Final facility location is still under consideration and the location stated is for cost evaluation purposes only.

The cost estimates created for this analysis were developed using the design criteria and unit costs identified in Table 2-6. Cost estimates are based on a set of criteria and unit costs based on May 2007 price levels. Capital costs are escalated to 2014 price levels, projected construction midpoint, based on the average annual change in Engineering News Record San Francisco Construction Cost Index (ENR SF CCI) values between January 1996 (6546.74) and December 2006 (9108.66). The costs presented herein are based on conceptual level engineering and are assumed to be accurate to +50 to -30 percent of the actual cost. Final costs will depend on actual labor and material costs, competitive market conditions, actual site conditions, final project scope, implementation schedule, and other variables.

---

[4] Treatment system water recovery computed as volume of demineralized water divided by the sum of the volume of demineralized water and the volume of waste concentrate.

[5] Basis for the water recovery value used here is developed in Chapter 3

Table 2-6: Cost Estimate Development Criteria

Element	Value/Unit Cost
Deep Well Development Cost	$700/foot
Pipeline Installation Cost	$8.00/inch diameter/lineal foot
Pipeline Appurtenances	10% of pipeline cost
Consumables (equipment, mechanical, electrical, instrumentation)	2% of capital cost
Electricity Costs	$0.15/kWh
Operator Labor	$60/hour
Cost Estimate Reference	May 2007
Cost Estimate Index (ENR SF CCI)	9116.72
Annual Inflation Rate (average annual EDR SF CCI increase over past 10 years)	3.9%

Table 2-7 summarizes the capital costs and Table 2-8 summarizes the annual operations and maintenance costs for the groundwater extraction and conveyance portions of the demineralization project. Scenarios analyzing both 83% and 98% water recovery are developed to allow for comparison of the impacts of various downstream processes. Costs for additional portions of the project are developed and presented separately.

Table 2-7: Groundwater Extraction & Conveyance Capital Cost Estimate

Component	Cost Estimate (83% Water Recovery)	Cost Estimate (98% Water Recovery)
Groundwater Wells	$2,444,000	$2,095,000
Groundwater Piping	$1,056,000	$981,000
Other Elements	$150,000	$129,000
Raw Construction Cost	**$3,650,000**	**$3,200,000**
Project Contingency (30%)	$1,100,000	$960,000
Change Order Contingency (5%)	$240,000	$210,000
Engineering/Environmental Allowance (20%)	$950,000	$830,000
Legal/Administrative Allowance (10%)	$480,000	$420,000
Construction Management Allowance (10%)	$480,000	$420,000
Total Capital Cost (May 2007)	**$6,900,000**	**$6,040,000**
Annualized Capital Cost (30 year, 5%, 2007)	**$449,000**	**$393,000**
Total Capital Cost (June 2014)	**$9,020,000**	**$7,890,000**
Annualized Capital Cost (30 year, 5%, 2014)	**$587,000**	**$513,000**

Table 2-8: Groundwater Extraction O&M Cost Estimate

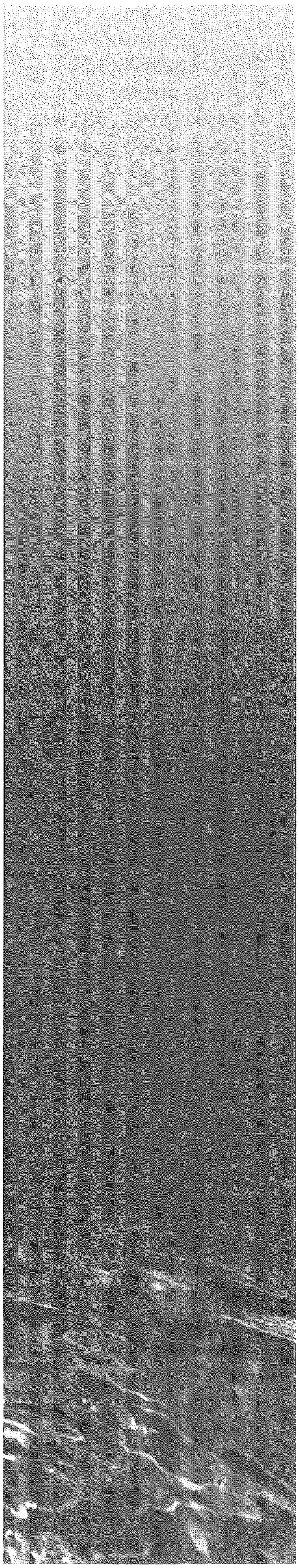
Component	Cost Estimate (83% Water Recovery)	Cost Estimate (98% Water Recovery)
Consumables	$39,000	$34,000
Energy	$67,000	$58,000
Labor	$12,000	$12,000
Total Annual O&M Cost (2007)	**$119,000**	**$105,000**
Present Worth O&M Cost (30 year, 5%, 2007)	**$1,830,000**	**$1,610,000**
Total Annual O&M Cost (2014)	**$159,000**	**$135,000**
Present Worth O&M Cost (30 year, 5%, 2014)	**$2,440,000**	**$2,080,000**

2.9 Recommendations and Next Steps

Based on the foregoing analysis, a wellfield at the Highway 156 location extracting 3,050 AFY to 3,860 AFY from deep wells offers the greatest overall benefits. This location is central and provides significant groundwater level and groundwater salinity management benefits to the northwestern portion of the San Juan Valley and has minimal salinity impacts on existing upgradient wells. This location is also sufficiently far from the DWTP and Whittaker/McCormick-Teledyne contamination sites to ensure that any groundwater originating from those areas would not arrive at the wellfield for at least 25 years.

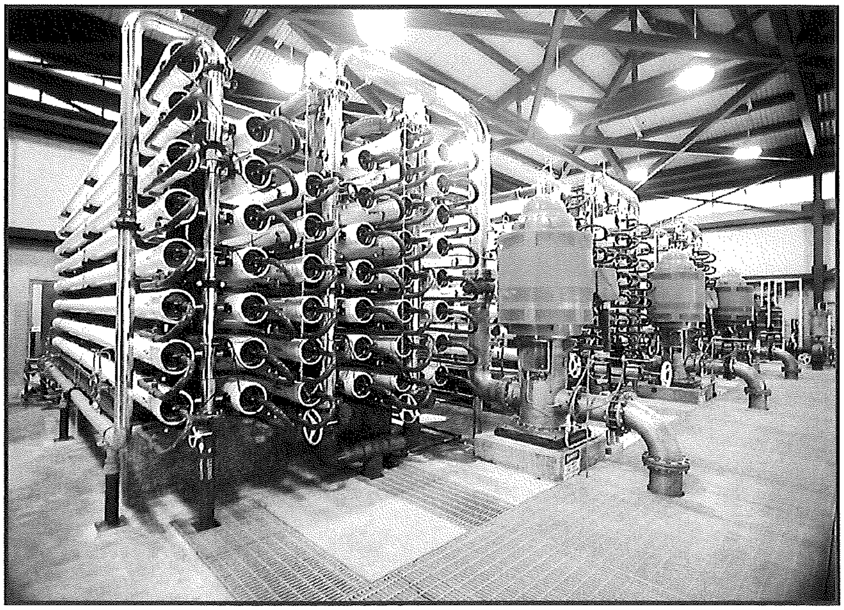
The next steps in the development of the demineralization supply wellfield include:

- Evaluation of water rights issues related to extractions for municipal use from the San Juan Valley
- Evaluation of property acquisition needs and available public rights of water for wells and pipeline infrastructure
- Preliminary consultation with the Department of Public Health for new potable water supply wells in the San Juan Valley and treatment requirements, if any, in addition to demineralization
- Preliminary design and layout of the wells and pipeline infrastructure



Chapter Three

Treatment Technology Assessment



Pajaro River Watershed Groundwater Desalination Feasibility Study

Chapter 3 Treatment Technology Assessment

3.1 Evaluation Criteria

The four technologies under consideration for brackish groundwater demineralization in the San Juan Valley Sub-Basin were compared using a series of eight criteria. The criteria were selected to provide information on all aspects of the treatment technologies and identify the main strengths and weaknesses of each. The eight criteria, described in detail in the following sections, are:

- Product Water Quality
- Water Recovery
- Constituent Removal
- Energy Use
- Waste Stream Management
- Pre-Treatment & Chemical Addition
- Post-Treatment & Disinfection
- Cost

3.1.1 Product Water Quality

The treatment technologies were assessed based on the ability to satisfy regulatory requirements for potable water as well as stakeholder goals with respect to water quality. The regulatory and stakeholder water quality criteria are presented below.

Regulatory Requirements

At a minimum, the final project will produce water that will meet all Environmental Protection Agency (EPA) and California Department of Public Health primary and secondary standards. Due to the demineralization processes being examined as potential treatment methods, it is anticipated that achievement of these standards will not be an issue.

There are currently no pathogen treatment (filtration and disinfection) requirements for groundwater systems. The US Environmental Protection Agency has finalized a Groundwater Rule, which includes monitoring and corrective action for groundwater systems that show serious deficiencies, however, treatment requirements are only included for systems where fecal contamination has been identified. In those cases, treatment would be required to provide 4-log (99.99%) removal of viruses. Additionally, compliance with the Total Coliform Rule (TCR) is required, which primarily addresses coliform bacteria in the distribution system. Typical groundwater systems often find that they need to add chlorine to comply with the TCR, but this is most often done to ensure that there are no coliforms in the distribution system rather than to meet specific removal/inactivation requirements. Distribution system disinfection is a good practice, but it is not strictly required for groundwater systems at this time.

The proposed treatment system may be subject to the Surface Water Treatment Rule (SWTR)[6] depending on the results of the determination of whether the selected groundwater wells are under the direct influent of surface water. This determination will be conducted at a later stage in the planning process and will identify whether or not the treatment system is subject to the requirements of the SWTR. Additionally, all other state and federal standards for drinking water quality will apply to the project regardless of this surface water/groundwater determination. If subject to the SWTR, the technology selected will have to achieve at least 99 percent (2-log) reduction of *Cryptosporidium*, 99.9 percent (3-log) reduction of *Giardia*, and 99.99 percent (4-log) reduction of viruses, in addition to other operational and distribution system-related requirements. Based on the concentrations of pathogens found in the source water, this treatment facility may be required to demonstrate pathogen treatment beyond these "baseline" levels.

---

[6] Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources (Surface Water Treatment Rule) 1989 40 CFR 141.70 - 141.75; and Interim Enhanced Surface Water Treatment Rule (IESWTR) 40 CFR 141.170-141.175 1998; and Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) 2002 40 CFR 141.500 - 141.571; and Filter Backwash Recycling Rule (FBRR) 2001 CFR 141.76 and Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) 2006 71 FR 654 January 5, 2006 vol. 71 no. 3.

The State of California Department of Public Health (CDPH) Drinking Water Program will make the final determination on the level of virus, *Cryptosporidium* and *Giardia* treatment required for any implemented potable water treatment facility. Direct measurement of pathogens in water is difficult, expensive, and not timely. Therefore, rather than demonstrate pathogen treatment by measurement of the pathogens themselves, the regulations credit particular treatment technologies with particular degrees of treatment (either removal or inactivation) which are based on controlled studies. If a plant is operated properly (according to a set of prescribed conditions), it will be credited with a particular amount of pathogen treatment and deemed capable of achieving the required level of pathogen removal.

The treatment technologies most commonly used on surface water have been evaluated by CDPH, and their pathogen removal effectiveness has been demonstrated. CDPH considers any type of surface water treatment technology not specifically mentioned in the SWTR to be an alternative technology. There are only four specific treatment technologies identified:

- Conventional treatment (coagulation, flocculation, sedimentation, filtration)
- Direct filtration (which is the same as conventional treatment without sedimentation)
- Slow sand filtration
- Diatomaceous earth filtration

All other treatment systems are defined as "alternative technologies" and must be validated for pathogen removal/inactivation prior to approval for operation. Examples of previously approved alternative technologies include in-line filtration (coagulation followed by filtration) and all forms of membrane filtration. A variety of manufacturers have had specific microfiltration, ultrafiltration or nanofiltration membranes approved through this process and the use of any of these accepted membranes would not require any additional validation.

CDPH is currently considering adopting a 2 log reduction credit for reverse osmosis without a study in recognition of the high removal efficiency of the process; however this is not yet adopted. Other technologies such as elecrodialysis reversal would require a demonstration study to verify any potential removal credits. CDPH has established a program for the approval of alternative technologies and each technology is evaluated on a case-by-case basis. Table 3-1 summarizes the log removal credits typically given by CDPH for elements of a potable water treatment process train. In this table, "unknown" means that no demonstration study has been conducted for this technology at this time. In order to use these technologies for pathogen removal, a CDPH-approved alternative technology assessment would have to be completed.

Table 3-1: Log-Removal Credits for Typical Treatment Technologies

Treatment Element	*Cryptosporidium*	*Giardia Lamblia*	Virus
Aquifer Filtration (bank filtration)	0.5-1.0	0.5-1.0	none
Granular Media Filtration	1-3.5	1-3.5	Up to 2
Cartridge Filtration	1-3	1-3	none
Microfiltration	3.5-4	3.5-4	0 - 1.5
Ultrafiltration	4	4	1.5-4
Nanofiltration	3	3	2
Reverse Osmosis	2*	2*	2*
Electrodialysis Reversal	None	None	None
Thermal Distillation	Unknown	Unknown	Unknown
Chlorine Disinfection	None	0.5 - 3	>4
Ultraviolet Disinfection	>2	Up to 4	>4
Ozone Disinfection	0.5 - 2	Up to 4	>4

Note: The disinfection technologies shown have varying amounts effectiveness depending on how they are operated.
* - Pathogen removal credit is currently not known, but CDPH guidance suggests pathogen removal credit will be applied based on proven salt removals. Recent applications indicate that approximately a 2-log removal will be credited.

The information presented in Table 3-1 regarding the removal credits for various types of membranes has an apparent anomaly in terms of the credits allowed for the four membrane filtration technologies (micro-, ultra- and nanoiltration and reverse osmosis). The credits allowed do not appear to be consistent with the size of the particles that can pass through the membrane. Using that basis, reverse osmosis should be given the largest number of removal credits and microfitlration the least number of credits. However, two main factors provide the basis for the credits shown in Table 3-1, and these are described below.

- Many of the RO membranes have not been tested to demonstrate their pathogen removal rates, while most microfiltration (MF) and ultrafiltration (UF) membranes have. Specific studies must be performed on a pilot scale involving spiking known concentrations of the pathogens into the feed water and measuring the concentrations in the effluent in order to get the removal credits. Once these studies are completed for one membrane, that membrane can then be used in other water systems without having to repeat the study. A list of all of the currently-approved technologies and their removal credits is maintained by CDPH. The use of RO for treatment of surface water is still rare enough that the manufacturers have not performed these pathogen-removal studies, while the use of MF and UF for surface water treatment is becoming more common.
- The few studies that have been performed to assess pathogen passage through RO membranes have shown that pathogens are sometimes found in the RO effluent. This is likely due to imperfections in the membrane and/or small gaps in the seals or o-rings. While some of these studies are old, and manufacturing processes have improved, CDPH is taking a cautious approach. Until the pathogen spiking studies are completed, they will be very conservative in awarding pathogen removal credits.

Using the credits summarized in Table 3-1, a "typical" groundwater demineralization system using cartridge filtration, reverse osmosis and ultraviolet disinfection on groundwater drawn through an aquifer would result in a minimum of 5.5 log removal of *Cryptosporisium* (0.5 log aquifer, 1 log cartridge filters, 2 log RO, 2 log UV), 5.5 log removal of *Giardia* (0.5 log aquifer, 1 log cartridge filters, 2 log RO, 2 log assumed UV) and 6 log removal of virus' (2 log RO, 4 log UV). These removal credits easily meet the minimum requirements for surface water treatment. If the source water is found not to be influenced by surface water, and therefore not subject to the SWTR, these requirements are not applicable. Regardless, groundwater supplies need to comply with the TCR criteria along with other drinking water standards. For the purposes of this evaluation, it is assumed that the water supply will be classified as groundwater and not be subject to surface water regulations.

Stakeholder Goals

According to the MOU that governs the Hollister Urban Area Water and Wastewater Master Plan (HUAWWMP), potable water quality goals include:

- 500 mg/L total dissolved solids (TDS) concentration
- 120 mg/L hardness as calcium carbonate ($CaCO_3$)

These goals are not for each individual water source serving the Hollister Urban Area but are to be representative of the weighted average over the potable water system.

3.1.2 Water Recovery

Each demineralization process under consideration produces product water and a waste concentrate containing the removed constituents and a portion of the influent water as a carrier. The quantity and concentration of this waste stream will vary depending on the technology chosen and the specific composition of the feed water. For the Pajaro River Watershed, an inland location with no existing waste stream management option such as an ocean outfall, maximizing the water recovery is anticipated to be important to realizing a cost-effective waste stream management strategy. Maximum water recovery would provide the most efficient use of the water extracted from the groundwater basin. There is a range of water recovery efficiencies available for most technologies from which to choose to meet the requirements of the chosen concentrate management system.

3.1.3 Constituent Removal

Each demineralization technology has different removal efficiencies for various constituents found in the feed water. Certain minimum removal efficiencies will be required to meet the product water quality requirements for the project. The estimated efficiencies will be obtained from the technology manufacturers and from operational experience at other similar facilities. The constituents to be compared are summarized in Table 3-2. While each technology removes more than just these listed constituents, the constituents listed in Table 3-2 will be used for comparative purposes of the identified technologies.

Table 3-2: Constituents for Removal Efficiency Comparison

Constituents	
Calcium (Ca)	Potassium (K)
Chloride (Cl)	Sodium (Na)
Flouride (F)	Sulfate (SO_4)
Magnesium (Mg)	Total dissolved solids (TDS)
Nitrate (NO_3)	

3.1.4 Energy Use

Regardless of the technology chosen, demineralization requires significant energy inputs to provide the required energy to physically separate the dissolved constituents and the product water and therefore remove the dissolved constituents from the product water. This energy is imparted to the water through pressurization of the influent water to overcome the osmotic pressure, development of an electromagnetic field or heating of the water. Energy use is dependent on system parameters and the desired removal rates, in general higher removal efficiencies are possible with higher energy inputs. With the cost of energy continually rising, this parameter has a significant impact on the operating cost of the facility and will impact process selection.

3.1.5 Waste Stream Management

The waste streams generated from demineralization need to be metered and disposed of in a manner commensurate with their composition. Some major considerations for waste stream management are:

- Waste stream classification: Identification of the waste stream as either hazardous or non-hazardous will change the available methods for final disposal
- Waste stream volume: A more efficient demineralization process will produce a smaller volume of waste material for disposal, which typically reduces the cost and operational complexity of the disposal system
- Water content: A waste stream that has a higher water content represents water that is "lost" from the potable water system. Higher water recoveries provide more potable water per unit of pumped groundwater and produce a waste stream with a lower water content, reducing the weight of material for disposal.

Each technology will produce at least one waste stream comprising the rejected dissolved constituents in some quantity of carrier water. The management of this waste stream, called "concentrate" or "brine", is specifically addressed in Chapter 4. Additionally, some of the technologies require periodic cleaning with chemical solutions that will require identification and development of disposal or other management methods. The main parameters for this criterion are waste stream quantity and quality. Both of these factors will influence the available methods for the handling of these waste streams.

3.1.6 Pretreatment and Chemical Addition

Certain demineralization technologies will require feed water with specific characteristics. Achieving these characteristics can require pretreatment of the feed water. Typical pretreatment options include cartridge filtration and chemical addition. Cartridge filtration would typically consist of a 5 to 10 micron filter to remove large suspended particles from the feed water thereby protecting the demineralization process from any negative impacts. Typical negative impacts include membrane blinding by large particles, introduction of biological organisms into the membrane system which can blind membranes as colonies grow and physical damage to the membranes from particles in the feed water. The specific size and composition of particles in the feed water will determine the specific problems that can occur within a membrane system in the absence of pretreatment filtration. Chemical addition requirements are dependent on the scaling potential of the influent water and the demineralization method used. Feed waters with a high scaling potential may require the addition of an anti-scalant to the feed water while other waters may require pH adjustment before the demineralization process. Other specific constituents that may need to be addressed are iron, manganese and natural organic compounds. The need for these additional components will impact the capital cost as well as the operational complexity of the facility.

3.1.7 Post-Treatment and Disinfection

The treated water quality from the demineralization treatment process will vary depending on the technology chosen. Some technologies, such as reverse osmosis, may require additional conditioning processes for their treated water to reduce potential chemical imbalances before introduction into the potable water system. Each technology may need additional disinfection depending on the source water determination.

3.1.8 Cost

The final criterion to be evaluated will be the cost of the treatment process. This cost analysis includes the capital cost of the major demineralization treatment components required for production of water meeting the water quality requirements as well as the two main aspects of annual operations and maintenance costs: energy use and membrane replacement. Additionally, other major elements differentiating the capital costs between the different demineralization technology alternatives will be identified but not quantified. The main basis of comparison will be the costs required per one million gallons per day (MGD) of product water. The primary sources for capital costs are budget proposals obtained from the major process vendors for each of the technologies. Final costs will depend on actual labor and material costs, competitive market conditions, actual site conditions, final project scope, implementation schedule, and other variable factors.

3.2 Technology Assessment

Table 3-3 identifies the four technologies under consideration and provides a basic description of how each removes dissolved constituents from the feed water. The technologies are further described in the following sections, which also evaluate the technologies according to the criteria identified in the previous section. Vendor proposals used in the development of the evaluation are included as Appendix C.

Table 3-3: Demineralization Technology Summary

Technology	General Methodology
Reverse Osmosis	Membrane separation
Electrodialysis Reversal	Removal of charged ions using a reversing electric field and anion/cation selective membranes
Nanofiltration	Low pressure membrane separation
Thermal Distillation	Evaporation and re-condensation of water, leaving dissolved constituents behind as a solid

As part of this Feasibility Study, preliminary proposals were requested and received from process vendors. The vendors were provided with a water quality sample from the San Juan Sub-Basin which was used as the basis for their assumptions and analyses[7]. Additionally, in conjunction with this Feasibility Study, Stanford University performed pilot testing of a reverse osmosis treatment unit in the San Juan Valley. This pilot unit provided significant data between March and April 2007 and the results from this testing are included as Appendix D to provide additional insight into the operation of membrane demineralization facilities in this area.

3.2.1 Reverse Osmosis

Overview

Reverse osmosis (RO) is a membrane separation process that operates by overcoming the osmotic pressure between the water and the compounds dissolved in it. The process was first developed at the University of California Los Angeles (UCLA) in the late 1950s by Sidney Loeb and Srinivasa Sourarijan. In 1965 the first commercial RO facility was designed and constructed in Coalinga, CA for demineralization of 6,000 gallons per day of brackish groundwater for potable use. The membranes used at that time were made of cellulose acetate polymer. Cellulose acetate (CA) membranes are composed of three main layers: a dense surface skin, a porous substructure and a reinforcing layer to provide structural support.

Recently, thin film composite (TFC) membranes have seen increased use and have replaced CA membranes in many applications. Like CA membranes, TFC membranes have three main layers: an ultrathin barrier layer, a microporous support layer and a structural reinforcing layer. Table 3-4 summarizes the differences between CA and TFC membranes. Most modern reverse osmosis facilities utilize TFC membranes for salt removal.

---

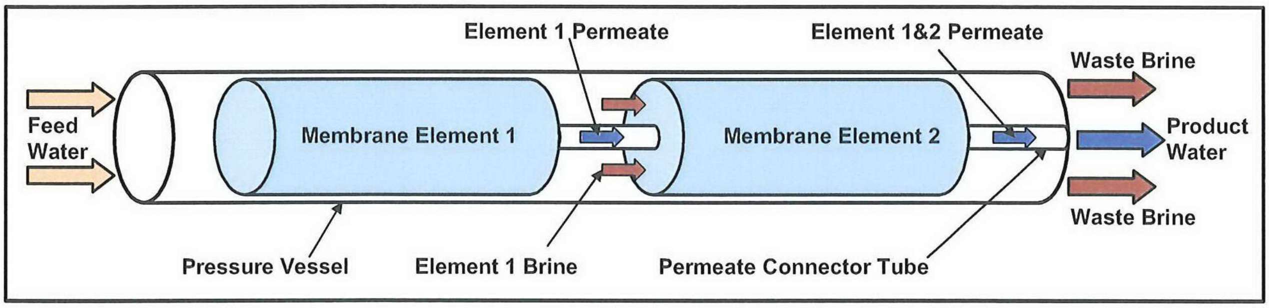
[7] Additional source water sampling is being conducted to provide a more representative assessment of groundwater conditions in the San Juan Valley. Revised analyses will be conducted to confirm previous results.

Table 3-4: Reverse Osmosis Membrane Summary

Membrane Material	Advantages	Disadvantages
Cellulose Acetate	• Tolerance to chlorine in the feed water • Low capital cost	• Subject to structural compaction • Higher energy requirements
Thin Film Composite	• Higher solute rejection capabilities • Higher flux rates	• Varying degrees of tolerance to chlorine in the feed water • Higher capital cost

Reverse osmosis works by feeding high pressure water into a pressure vessel containing a series of membrane elements. The denser the membrane and the higher concentration of dissolved solids in the feed water, the higher pressure is required for the process. Typically, several membrane elements are contained in the same pressure vessel so that the concentrate from each element is the feed water for the following element. Similarly, multiple pressure vessels are organized into a stage where the concentrate from each stage is the feed water for the subsequent stage. Brackish groundwater reverse osmosis systems typically have 2 or 3 stages. Figure 3-1 shows a schematic representation of the fluid flow within a pressure vessel.

Figure 3-1: Reverse Osmosis Vessel Schematic



Product Water Quality

RO has the ability to produce water that will meet all stakeholder water quality goals as well as CDPH primary and secondary drinking water standards. RO removes the majority of the TDS and the hardness present in the source water to provide water that will easily meet the stakeholder goals set for the HUAWWMP. The use of this demineralized water in the distribution system would also assist the Hollister Urban Area to meet these stakeholder goals on a system-wide basis. As summarized in Table 3-1, the RO process typically receives a 2 log removal/inactivation credit from CDPH for pathogen removal, when required based on the applicability of the SWTR. Typically in cases where the SWTR is applicable, some amount of disinfection is required following RO to meet the removal/inactivation requirements.

Water Recovery

The water recovery of a reverse osmosis system is dependent on the number of stages utilized in the process. The membrane selected and the feed water quality are the primary variables in determining the water recovery of the RO unit. Typical values for water recovery are about 50 percent per stage. Therefore, for a 2-stage system, 70 – 75 percent water recoveries are typical and for 3-stage systems, 75 – 85 percent recoveries are common. In order to minimize the quantity of the concentrate and maximize the quantity of product water produced from the facility, a three-stage system would be typical.

Constituent Removal

Typical RO membranes have the ability to remove a variety of constituents from the feed water. Two reverse osmosis membrane options were reviewed for the purposes of this feasibility study. The two options provide varying removal efficiencies with different pressure requirements and flow limitations. Both membranes were FILMTEC™ brand membranes, manufactured by Dow Chemical, with one from their "extra low energy" product line (XLE-440) and one from their "brackish water" product line (BW30-400). These two example membranes demonstrate the range of typical reverse osmosis parameters.

The two membranes each remove varying percentages of different elements. Table 3-5 summarizes these removal rates, as provided through operation simulations based on a water quality sample provided by SBCWD for the San Juan Valley sub-basin and a RO system with approximately 75% water recovery. The removal efficiency shown in this table clearly demonstrates the removal efficiency dependence on pressure. The XLE product line utilizes a lower feed pressure than the BW product line and results in correspondingly lower removal rates. However, the BW membrane has a lower fouling potential, allowing for less frequent cleaning, but requires a higher feed pressure to separate the dissolved constituents from the feed water. The tradeoff between feed pressure and cleaning frequency can be an important parameter in the choice of a specific membrane for a demineralization facility.

Table 3-5: FILMTEC™ Membrane Removal Efficiencies

Constituent	XLE-440 Removals (extra-low energy product line)	BW30-400 Removals (brackish water product line)
K	71.2%	89.6%
Na	93.0%	98.2%
Mg	96.5%	99.1%
Ca	96.5%	99.1%
NO3	60.3%	85.5%
Cl	93.0%	98.7%
F	90.9%	97.0%
SO4	97.5%	99.4%
TDS	94.1%	98.4%

The three critical parameters for meeting stakeholder potable water quality criteria are TDS, magnesium (Mg) and calcium (Ca). The TDS concentration goal is specifically defined as 500 mg/L while Mg and Ca are the two primary components of hardness which has a goal of 120 mg/L. RO systems can produce water that meets these standards and blending with untreated groundwater at the treatment facility would likely be implemented to maximize the overall facility capacity while maintaining high water quality.

Additionally, the sodium concentration in the potable water is directly related to the sodium concentration in recycled water that is ultimately planned to be distributed to agricultural irrigation customers. This recycled water will need to have a sodium absorption ratio (SAR) acceptable for use on the crops grown by these customers. The SAR is the concentration of sodium (in micro moles per liter) divided by the square root of half the sum of the calcium and magnesium concentrations (also in micro moles per liter). The RO process is effective at reducing the SAR from a raw groundwater value of approximately 6.0 to a permeate value ranging from 1.17 (BW membrane) to 2.25 (XLE membrane). In the absence of residential water softeners, the SAR of the wastewater is not anticipated to vary significantly from the potable water SAR.

Energy Use

There are several elements of the reverse osmosis treatment facility that require energy inputs. The largest energy user is the feed pump for the reverse osmosis membranes. This pump must pressurize the entire influent flow to a level that will exceed the osmotic pressure of the water at the feed point of the last membrane element in the last stage. The Severn Trent systems identified a two-stage system with 16 pressure vessels in the first stage and 8 pressure vessels in the second stage with 7 membrane elements in each pressure vessel. Within a RO module, the feed water to each element, except the first element, is the concentrate from previous element(s). Table 3-6 summarizes the required feed pressure at this point as well as other critical energy use criteria for each membrane system. Typical three stage systems would require additional feed water pressure and result in larger feed water pumps and increased TDS concentrations entering the final element.

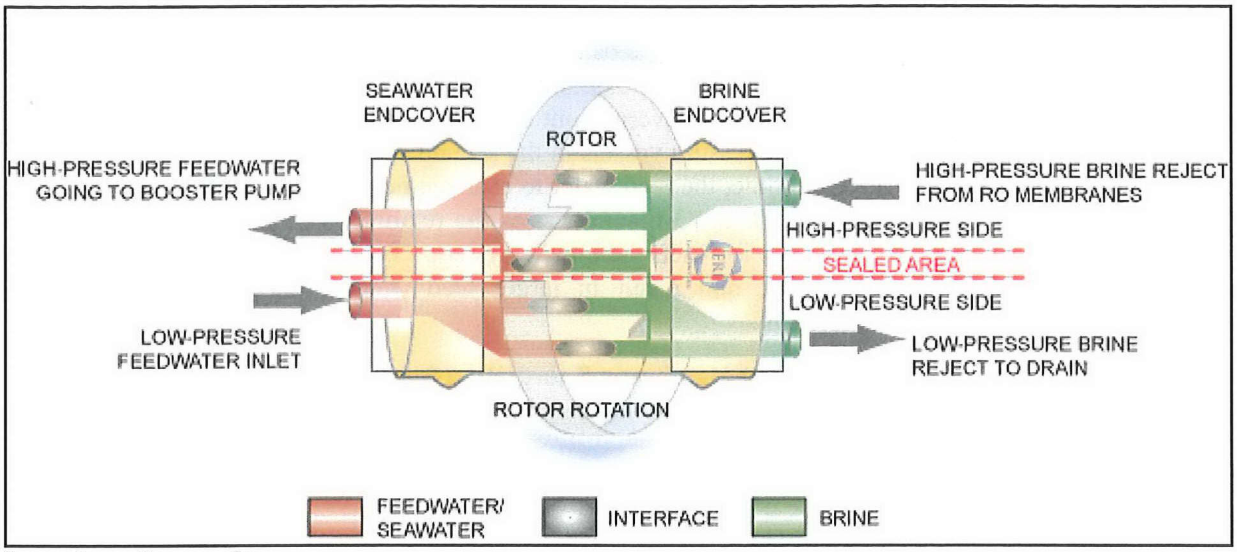
Table 3-6: RO Membrane Energy Use Summary

Criteria	XLE Membranes	BW Membranes
TDS of water entering final membrane element *	7,100 mg/L	7,000 mg/L
Feed water pressure required	115 pounds per square inch (psi)	193 psi
Feed pump power	100 HP	150 HP
Specific energy use (feed water pump only)	1.45 kilowatt-hours per 1,000 gallons of product water (kWh/1,000 gal)	2.39 kWh/1,000 gal

* - Assumes feed water TDS = 1,900 mg/L. This value was adjusted from measured values to reflect a balanced ionic condition in the feed water.

A relatively recent development to reduce the RO energy consumption is the energy recovery device. These devices are typically found in seawater desalination applications where pressures are higher and recoveries are typically lower, resulting in a higher potential for energy recovery. Typically, the concentrate stream of a RO unit leaves the pressure vessel at a lower pressure than the applied pressure from the high-pressure pump. The energy recovery device, consisting of pressure exchangers, turbines, or pumps of some kind, converts the remaining pressure in the waste concentrate to rotational or other forms of energy that can be reused in the process of pressurization. Energy Recovery, Inc (ERI) produces a pressure exchanger specifically designed for brackish groundwater applications which operate at lower pressures and higher water recoveries. Figure 3-2 shows how a pressure exchanger (PX) operates. Essentially, the high pressure concentrate provides the force to pressurize the influent feed water to a level close to what is required for the demineralization process. A small booster pump is required on the feed water exiting the PX to account for minor losses through the RO and PX systems. The resulting system reduces the required capacity of the high pressure feed pump which results in energy cost savings.

Figure 3-2: Pressure Exchanger Operation


SEAWATER ENDCOVER
BRINE ENDCOVER
ROTOR
HIGH-PRESSURE FEEDWATER GOING TO BOOSTER PUMP
HIGH-PRESSURE BRINE REJECT FROM RO MEMBRANES
HIGH-PRESSURE SIDE
SEALED AREA
LOW-PRESSURE SIDE
LOW-PRESSURE FEEDWATER INLET
LOW-PRESSURE BRINE REJECT TO DRAIN
ROTOR ROTATION
FEEDWATER/ SEAWATER
INTERFACE
BRINE

Source: Energy Recovery, Inc.

Of the two RO system options evaluated, only the BW membrane system provides a concentrate stream with sufficient pressure to justify the use of the PX device. For the BW membrane system, ERI identified a pressure exchanger system that estimates a power saving of 0.24 kWh per 1,000 gallons of permeate produced, a reduction of approximately 10 percent. The XLE membrane system, on the other hand, has a relatively low concentrate pressure and can not be efficiently coupled with a PX device. Further evaluation of the benefit:cost ratio for this device would be required prior to implementation in a full-scale system.

The PX device is one of the few energy recovery devices intended for use with brackish water RO systems however, there are some concerns about a potential cross connection between the waste concentrate and the RO membrane feed water. This potential is still being evaluated and no official position has been taken by CDPH to this point.

Other energy requirements for the RO system will include cleaning solution pumps, building lighting, control systems, chemical pumps and product water pumps.

Waste Streams

The RO treatment process produces two main waste streams. The first, a continuous flow, is a highly concentrated brine solution. This waste product is composed primarily of the dissolved constituents separated from the feed water by the semi-permeable membrane. The handling and management of this waste stream is addressed separately in the brine management section of the analysis (Chapter 4).

The second waste stream results from periodic clean-in-place (CIP) cycles. These cycles consist of filling the pressure vessels with a chemical solution that remove minerals that have fouled the surface of the membrane. Typically, this waste stream is discharged to the sanitary sewer system, however depending on the facility location there may not be an available sewer connection. In this case, an alternative disposal method would be needed. Depending on the volume of waste cleaning solution generated each cycle, a tank could be used to collect the waste solution for periodic hauling to a treatment or disposal facility.

Pretreatment & Chemical Addition

RO units typically require feed water with a maximum silt density index (SDI) of 5 and a maximum turbidity of 1 Nephelometric Turbidity Units (NTU). These requirements can typically be met using cartridge filters upstream of the membrane units, and are typically found on RO systems treating groundwater supplies.

Due to the reliance on the membranes for treatment and the potentially large impact on membrane flux rates by fouling and scaling, the quality of the feed water is very important to the effectiveness of the RO unit. Membrane fouling, very problematic for RO processes, can be generally traced to four sources: scaling, dissolved organics/suspended colloids, suspended organics and biofouling.

- **Scaling** is caused by dissolved calcium and magnesium precipitating onto the membrane surface due to the chemical properties of the water. The two critical parameters are silica concentrations and SDI. Solutions for this type of fouling include pH adjustment, injection of a scale-inhibiting chemical or a reduction in the feed pressure. Brackish groundwater demineralization systems typically utilize scale-inhibiting chemicals to control the impacts of silica and SDI. The silica concentration in the San Juan Valley groundwater is approximately 30 mg/L, which, following treatment through a three-stage reverse osmosis system would likely exceed the silica saturation concentration of 120 mg/L, after which membrane scaling would occur through the precipitation of silica compounds. Solutions to the scaling problems come at additional costs, either for chemical facilities or for the increased number of RO units needed to maintain the same product water flow.
- **Dissolved organics and suspended colloids** include small particles in the feed water that are too large for the membrane to effectively remove and are caught on the waste side of the membrane. This deposition can increase the required pressure to maintain the same permeate flow. The common solutions are to increase the prefiltration effectiveness or to clean the unit using a high pH solution.
- **Suspended organic compounds** can result in a dramatic decrease in flow across the membrane due to blinding of the membrane. If this occurs, the organics in the feed water need to be removed using additional treatment processes (such as microfiltration) or the membranes need to be altered to provide better compatibility with the feed water.
- **Biofouling** is a concern particular to RO since the main means of dealing with biofouling in other applications is with chlorine injection. Meanwhile, the current generation of RO membranes is largely intolerant to disinfection-level chlorine concentrations. Therefore, chlorination of the feed water followed by dechlorination upstream of the membranes would be required to protect the membranes from the biofouling as well as any chlorine used in the growth removal. Some membrane manufacturers are currently developing chlorine tolerant thin film membranes that could be disinfected to prevent biofouling in the system.

Post-Treatment & Disinfection

Depending on the feed water alkalinity and pH, the RO permeate may have high concentrations of carbon dioxide and may be corrosive to pipes, pumps, valves and other metal components. Decarbonation and adjustment of the permeate water chemistry can be performed to address distribution system concerns. In addition, disinfection may be required per regulations depending on the classification of the groundwater that will be the source for the treatment system. Also, chlorine addition may be desired to maintain a residual concentration in the distribution system. These processes add operational complexity, maintenance requirements and costs to the overall RO treatment system.

Recommended Treatment Train

The recommended RO treatment train consists of pretreatment using cartridge filters, reverse osmosis membranes, disinfection facilities (surface water only) and product water pumps. The potential need for decarbonation will be reviewed following completion of the pilot testing program. A 1.0 MGD RO system using the BW30-400 membranes would cost approximately $425,000, exclusive of site preparation, system installation, chemical facilities, building and system piping. The XLE-440 membranes would add some increased cost but this would be recovered via energy savings over 1.5 to 2 years. The addition of an ERI pressure exchanger would add approximately $33,000 to the capital cost but would result in an energy savings for the BW30-400 membrane system. This specific level of cost saving is contingent on the acceptability of the PX device to CDPH, which is yet to be finalized.

A more detailed cost analysis of the RO option is presented in Section 3.4.

3.2.2 Electrodialysis Reversal

Overview

Electrodialysis reversal (EDR) is a process that was born from the electrodialysis (ED) process. ED was first applied in 1953 to supply potable water for an oil exploration team in Saudi Arabia. After two decades of innovation on the ED process, the reversal of the direct current (DC) to drive scale from the membranes saw the first application of EDR in 1974. Reversing the DC current from one end of the stack to the other was intended to minimize concentration polarization at the membrane surface thereby reducing membrane fouling and precluding the injection of acids or anti-scalants into the stack. Concentration polarization is a general description of molecular/ion accumulation phenomenon, while scaling is the result of concentration polarization with some divalent ions. There is currently only one manufacturer of EDR units, Ionics, which is a part of the General Electric (GE) family of companies. Developments made by Ionics between 1974 and 1997 spawned a second generation of EDR technology that increased the operational efficiency of the process and made EDR viable for many applications that were traditionally served by reverse osmosis.

ED works by injecting raw water at low pressures into a spacer between an anion-selective membrane and a cation-selective membrane. At the same time, a charge differential is generated across the membrane stack. This differential provides an electromotive force that serves to pull charged ions from the raw water toward the electrodes. Where one spacer layer carries demineralized water, the two adjacent spacer layers carry the concentrated waste stream. A portion of the concentrate is then recirculated back to the influent of the stack which increases the overall water recovery of the system. The remainder of the concentrate is wasted to remove the ions from the process. The product water, with approximately 50 – 60 percent of the salts removed, can then be used or sent to a second stack for additional demineralization.

In the EDR process, the charge on the electrodes are switched several times per hour to reverse the flow of ions across each membrane and the spacer layers change function; the spacers carrying product water originally would now carry waste concentrate and vice versa. This process is a form of automated cleaning of the membranes to avoid fouling. Reversal of flow through the membrane will drive any scale that has formed on the membrane into the concentrate stream thereby minimizing the amount of permanent fouling that occurs. A set of automated valves enable the separation of product water and waste concentrate piping.

To increase salt removal efficiencies, EDR is typically run in two stages where the product water from the first stage is supplied as the feed water for the second stage. Figure 3-3 and Figure 3-4 show how the EDR process removes dissolved ions from the feed water. Automatic cleaning of the membrane surfaces is provided by switching the charges on the electrode at the ends of the stack so that the product water and concentrate channels are swapped and any ions that have precipitated onto the membranes are driven off by flow reversing through the membranes. These ions are then removed from the system in the concentrate stream.

Figure 3-3: EDR Ion Movement

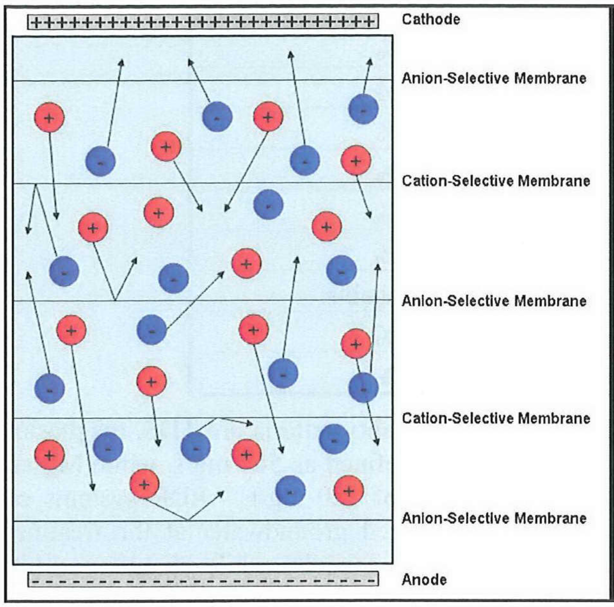
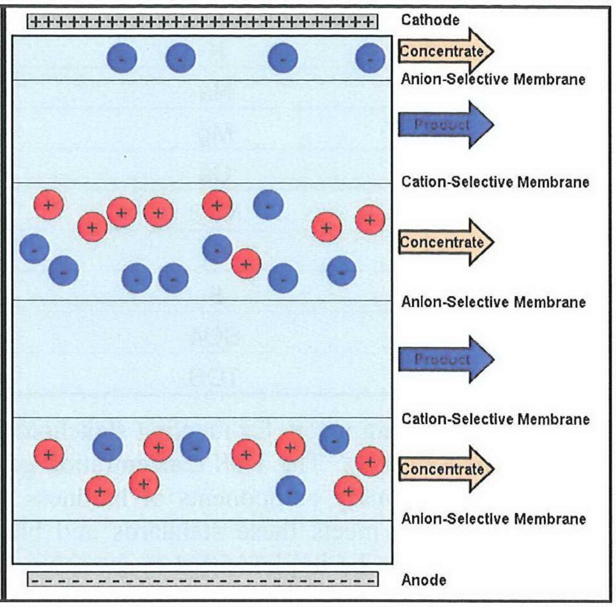


Figure 3-4: EDR Product & Concentrate Separation



Product Water Quality

An EDR treatment train has the ability to produce water that will meet stakeholder water quality goals and all CDPH primary and secondary drinking water standards. As summarized in Table 3-1, the EDR process will likely receive no removal/inactivation credit from CDPH for pathogen removal, when required based on the applicability of the SWTR. If the SWTR is applicable for this case, a significant amount of disinfection would be required to meet the removal/inactivation requirements. EDR removes the majority of the TDS and the hardness present in the source water to provide water that will easily meet the stakeholder goals set for the HUAWWMP. The use of this demineralized water in the distribution system would also assist the Hollister Urban Area to meet these stakeholder goals on a system-wide basis.

Water Recovery

EDR water recovery is a function of the number of and the arrangement of membrane stacks, the constituents present in the feed water and the quantity of concentrate recirculation. Typical two-stack systems have water recoveries ranging from 85 percent to as high as 94 percent.

Constituent Removal

Typical EDR systems remove a variety of ions from the feed water. The removal efficiencies are proportional to the strength of the voltage field potential which can be controlled by varying the voltage applied to the electrodes. Therefore, EDR units can produce water with a TDS concentration that just meets the water quality criteria while operating at the optimum electrical efficiency.

Table 3-7 summarizes general removal efficiencies for several constituents.

Table 3-7: Example EDR Removal Rates

Constituent	EDR Removals
K	58%
Na	64%
Mg	62%
Ca	50%
NO3	69%
Cl	63%
F	Not available
SO4	71%
TDS	75%

The three critical parameters for meeting stakeholder potable water quality criteria are TDS, magnesium (Mg) and calcium (Ca). The TDS concentration goal is specifically defined as 500 mg/L while Mg and Ca are the two primary components of hardness which has a goal of 120 mg/L. EDR systems can produce water that meets these standards and blending with untreated groundwater at the treatment facility would likely be implemented to maximize the overall facility capacity while maintaining high water quality. Due to the lower removal rates from EDR systems, a larger quantity of product water would be needed to deliver blended water of the same quality as from RO. The EDR unit is anticipated to produce product water with a SAR of approximately 5.1, providing minimal reductions as compared to local groundwater and likely requiring additional conditioning for recycled water prior to distribution to agricultural customers.

Energy Use

As a voltage-driven process, EDR's largest energy use is the direct current required to separate the ions in the membrane stacks. The direct current is supplied through a rectifier that transforms alternating current to direct current. A secondary energy use is the low pressure circulating pump that operates at 50 psi or lower. The pump needs to provide sufficient power to overcome the resistance of the water as it passes through the membrane stacks. To provide 1.0 MGD of product water, three GE/Ionics EDR 2020 units in series would be required. This system arrangement will consume about 4 kWh of power per 1,000 gallons of product.

Other energy requirements include building lighting, control systems, cleaning solution pumps and product water pumps.

Waste Streams

The EDR treatment process produces a highly concentrated brine. This waste stream is composed mainly of the ions that migrate across the membranes as a result of the voltage differential. In addition, the waste stream also carries the scales, slimes, and other deposits that are flushed out from the membrane stacks during the first one or two minutes after the polarity of the electrodes is reversed. The handling and management of this waste stream is addressed in a separate chapter. Periodic disposal for waste cleaning solutions is also required, similar to that required for the reverse osmosis process.

Pretreatment & Chemical Addition

Since the EDR process does not utilize a membrane barrier between the feed water and the product water, the feed water quality is subject to different constraints than RO feed water. EDR units are subject to less severe impacts from silica and SDI than RO units because the reversal of the ion flow through the membranes several times per hour results in an inherent cleaning mechanism. This cleaning mechanism removes precipitated solids from the membrane face, allowing ions present in the feed water to continue to pass through the membrane and be removed from the product water. EDR units can reliably treat feed water with SDI levels up to 15 and turbidity values of up to 2 NTU. Also, the membranes that are used are less sensitive to free chlorine in the feed water than typical TFC RO membranes. The main concerns for EDR units are large particles that could plug the spacers. Typically, these feed water constituents are addressed using disposable cartridge filters for pretreatment of the feed water.

Additional pretreatment might be needed if an oxidized form of iron is present in the feed water. If iron is present, an iron removal filter should be installed to prevent overloading the disposable cartridge filters. Once iron data are available for the source water, the need for such pretreatment can be assessed.

Post-Treatment & Disinfection

The product water from EDR units may be corrosive and may need to be chemically adjusted prior to distribution. Typically, post-treatment consists of removing gases and pH adjustment. In addition, disinfection may be required under the SWTR depending on the classification of the source water. If the water is determined to be "under the influence of surface water" the disinfection step will likely need to obtain all pathogen removal/inactivation since EDR units do not provide a physical barrier to viruses and bacteria between the feed water and the permeate. Additionally, chlorine injection may be included to maintain a residual concentration in the distribution system.

Recommended Treatment Train

Similar to RO, the EDR process results in a recommended treatment train of cartridge filters, electrodialysis stacks, disinfection facilities (surface water only) and product water pumps. A budget proposal from Ionics, for 1.0 MGD of EDR product water was $2,060,000 for the membrane system. The budget proposal provided by Ionics included the EDR stacks, cartridge filters, feed pumps and chemical facilities. Additional costs would be incurred for installation, a building and system piping. Due to the low pressure of the feed, the ERI pressure exchanger is not a viable energy recovery option for this demineralization technology.

3.2.3 Nanofiltration

Overview

Nanofiltration (NF) is similar to the reverse osmosis process in that water is forced, under pressure, across a membrane while certain dissolved constituents are prevented from crossing the membrane due to size differences between the constituent and the membrane opening. This process has been called "low pressure reverse osmosis" and "membrane softening" which refer to its ability to preferentially remove divalent ions (e.g. calcium and magnesium), rather than monovalent ions, from the feed water while requiring a lower pressure due to the larger openings in the membrane surface. This technology is used in drinking water applications mainly for the removal of color and hardness from the raw water. There are fewer installations that are using NF specifically for demineralization. However, the water quality goals for the Pajaro River Watershed would seem to indicate that NF can provide the required potable water quality.

Product Water Quality

A NF treatment train has the ability to produce water that will meet all stakeholder water quality goals and CDPH primary and secondary drinking water standards. As summarized in Table 3-1, the NF process typically receives a 2 to 3 log removal/inactivation credit from CDPH for pathogen removal, depending on which pathogen is being considered and when required based on the applicability of the SWTR. Typically in cases where the SWTR is applicable, some amount of disinfection will be required following NF to meet the removal/inactivation requirements. NF removes the majority of the TDS and the hardness present in the source water to provide water that will easily meet the stakeholder goals set for the HUAWWMP. The use of this demineralized water in the distribution system would also assist the Hollister Urban Area to meet these stakeholder goals on a system-wide basis.

Water Recovery

Like RO, NF modules are arranged in stages to improve product recovery. Typically, the overall water recovery of a nanofiltration system is higher than that of a RO system. Values for water recovery range from 60-75 percent for a 1-stage system, 75-80 percent for a 2-stage system, and 85-90 percent for a 3-stage system.

Constituent Removal

Nanofiltration membranes typically have lower monovalent ions (e.g. Na and Cl) removal rates than RO membranes but are very effective in rejecting multivalent ions, organic matter, bacteria and viruses. One membrane that might be applicable for this application is a FILMTEC™ brand membrane, manufactured by Dow Chemical, featuring a high active area and low operating pressure requirements. This membrane will be used to demonstrate typical nanofiltration parameters through the following sections.

The FILMTEC™ NF90-400 membrane has overall lower constituent removals than the two RO units (XLE-440 and BW30-400) discussed in section 2.1. Table 3-8 summarizes the removal rates of the membrane unit as provided through operational simulations based on a water quality sample provided by SBCWD for the San Juan Valley.

Table 3-8: NF90-400 Removal Efficiencies

Constituent	NF90-400 Removals
K	57.5%
Na	87.4%
Mg	95.9%
Ca	96.0%
NO3	42.5%
Cl	82.1%
F	84.8%
SO4	98.1%
TDS	90.6%

The three critical parameters for meeting stakeholder potable water quality criteria are TDS, magnesium (Mg) and calcium (Ca). The TDS concentration goal is specifically defined as 500 mg/L while Mg and Ca are the two primary components of hardness which has a goal of 120 mg/L. NF systems can produce water that meets these standards and blending with untreated groundwater at the treatment facility would likely be implemented to maximize the overall facility capacity while maintaining high water quality. NF provides Ca and Mg removal rates similar to that achieved with RO and would therefore require a product water capacity similar to that in an RO facility. A NF facility would reduce the SAR of the groundwater from 6.00 to approximately 3.74, which is well below critical levels for agricultural uses.

Energy Use

Like RO, the major energy requirement of a NF system is the feed pump. For the selected NF filter, the system feed water pressure requirement is approximately 100 psi, which is about 12 percent lower than what is required for the XLE RO membrane system based on the same water chemistry analysis. This requirement results in a need for an 80 HP pump for each 1.0 MGD of product water. The specific energy consumption is 1.42 kWh per 1,000 gallons of system permeate.

Other energy requirements for the NF unit will be similar to those for RO units.

Waste Streams

Like RO, the NF treatment process produces two main waste streams, a concentrated brine solution and a waste cleaning solution. Compared to RO, NF units typically produce a smaller volume of less concentrated brine solution because of the characteristics of the membrane and the lower rejection of dissolved constituents as compared to RO. The recovery rates of the NF and RO membrane systems evaluated for this application are both approximately 75 percent. Nonetheless, the waste stream produced in the NF units is less concentrated due to membrane characteristics. The handling and management of this waste stream is addressed separately in the brine management section (Chapter 4).

Pretreatment & Chemical Addition

Due to its similarity to RO treatment process, NF requires approximately the same level of feed water pretreatment. Ideal feed water for a NF system should have turbidity less than 1 NTU and silt density index (SDI) less than 5. Cartridge filters are used to remove bacteria and organic molecules that could result in biological fouling on the membrane surface. Antiscalant chemicals are added to prevent scaling and precipitation of minerals on the membrane. Like RO membranes, the NF membranes are susceptible to biofouling and control of this problem may require chlorination and dechlorination as NF membranes are also typically TFC membranes with minimal chlorine tolerance.

Post-Treatment & Disinfection

Like RO, NF product water may be corrosive and may need chemical adjustment to prevent potential damage to distribution lines. In addition, disinfection may be required if the water source is classified as "under the influence of surface water" and chlorine injection may be added to provide a distribution system residual if desired.

NF units typically do not require any post-treatment in situations where the permeate will be blended with other water sources. However, a degassifier could be used to further adjust the chemical properties of the product water if deemed necessary.

Recommended Treatment Train

The recommended treatment train for a nanofiltration demineralization system consists of cartridge filters, nanofiltration membranes, disinfection facilities and product water pumps. To provide a 1.0 MGD NF system utilizing the NF90-400 membranes, the estimated is approximately $525,000, exclusive of site preparation, system installation, chemical facilities, a building and system piping. The addition of an ERI pressure exchanger would not be a viable energy recovery option due to the low feed pressure of the NF system.

3.2.4 Thermal Distillation

Overview

Thermal distillation is the oldest and most widely used desalination technology. This technology is a phase separation process in which saline water is heated to produce water vapor, which is then condensed to produce freshwater. Among the thermal desalination technologies, Multi-Stage Flash (MSF) and Multi-Effect Distillation (MED) are the better established processes, typically used for seawater desalination in the Middle East.

Thermal desalination is not as well established in the US as it is in the Middle East. Instead, the US desalination market is dominated by membrane processes, with RO leading the field. The widespread availability of affordable energy in the Middle East allows for economical operation of these extremely energy-intensive facilities. Energy in the United States is generally not available at costs that would allow for the same level of economic efficiency as is found in the Middle East.

Product Water Quality

The distillation process has the ability to produce water that will meet all CDPH primary and secondary drinking water standards. As summarized in Table 3-1, it is unknown what level of removal/inactivation credit will be awarded by CDPH for pathogen removal, when required based on the applicability of the SWTR. If the SWTR is applicable for this case, a significant amount of disinfection would be required to meet the removal/inactivation requirements. Distillation removes the majority of the TDS and the hardness present in the source water to provide water that will easily meet the stakeholder goals set for the HUAWWMP. The use of this demineralized water in the distribution system would also assist the Hollister Urban Area to meet these stakeholder goals on a system-wide basis.

Water Recovery

Water recovery rates for thermal desalination vary depending on the methods of distillation used and on site-specific conditions. Typical recovery rates for seawater desalination range from 15 to 50 percent.

Constituent Removal

Thermal desalination essentially removes almost all constituents in water, leaving a nearly pure distillate as product. The water product contains TDS ranges from 1.0 to 50 mg/L, while product water from RO units typically has TDS level that ranges from 10 to 500 mg/L. For this project, since product water will be blended with other water sources before distribution, such a high removal efficiency would be unnecessary.

Energy Use

Due to its operating principle, thermal desalination is an energy-intensive process. Although process requirements vary, thermal desalination can require up to 13 kWh of energy per 1,000 gallons of water produced. Approximately 97 percent of this energy consumption is for thermal energy to boil the water. The remaining 3 percent is electrical energy for other aspects of the process. To lower the energy requirement, most distillation processes, such as MSF, MED, and vapor-compression (VC), reduce the vapor pressure of water within the unit to allow water to vaporize at a lower temperature. Research is also being undertaken to study solar energy desalination, a distillation method with relatively lower energy requirements. Nonetheless, energy the requirements remain a major obstacle for thermal desalination in the US desalination market.

Operation of a thermal desalination system requires intensive knowledge of thermodynamic processes and constant monitoring of multiple pressurized vessels to ensure efficient operation. This complexity results in efficiencies that can only be achieved at larger facilities where common infrastructure can be used to generate a large volume of potable water.

Waste Streams

Like membrane desalination, thermal processes produce two main waste streams; a concentrated brine solution left behind after distillation and a waste chemical solution. The concentration and quantity of the brine solution depends on the recovery efficiency of the thermal plant. The handling and management of this brine is addressed in the following chapter.

Pretreatment & Chemical Addition

Typically, the feed water for thermal distillation does not require pretreatment or chemical addition.

Post-Treatment & Disinfection

The product water of thermal desalination is highly acidic and corrosive to distribution pipelines. Therefore, pH and other chemical adjustments will be necessary to prepare the water for distribution. In addition, due to the scarcity of thermal desalination projects in the United States, CDPH may require significant disinfection as a post-treatment to ensure that the product water complies with the standards for microbial contaminants.

Recommended Treatment Train

Based on the operational complexity, the uncertainty in the permitting process, the high energy consumption and the probable high capital costs resulting from severe economies of scale for this technology, thermal demineralization does not appear to be a viable alternative for the Pajaro River Watershed. The potential cost and schedule risks resulting from implementation of this technology are great and are not anticipated to be offset by a corresponding increase in benefits from the use of this technology.

3.3 Technology Comparison

Based on a preliminary evaluation of the four demineralization technologies, only one, thermal distillation, was immediately eliminated. The three remaining technologies were further analyzed with respect to the eight criteria. The following sections summarize the comparison of the technologies for each criterion.

3.3.1 Product Water Quality

RO, EDR and NF all have the ability to produce water that meets all primary and secondary regulatory standards and meet the goals set through the HUAWWMP process. The difference between the three technologies is in the additional pathogen removal/inactivation that may be required following the demineralization process. These needs are summarized in Section 3.3.7, but in general RO and NF will require the least additional disinfection to meet the removal/inactivation requirements should the source water be classified as "under the influence of surface water" while EDR would need a significant level of disinfection to meet these standards.

3.3.2 Water Recovery

Table 3-9 summarizes the water recovery ranges for standard arrangements for the three demineralization technologies. EDR has the ability to provide the highest water recovery, followed by NF with RO providing the lowest water recovery for the technologies under consideration.

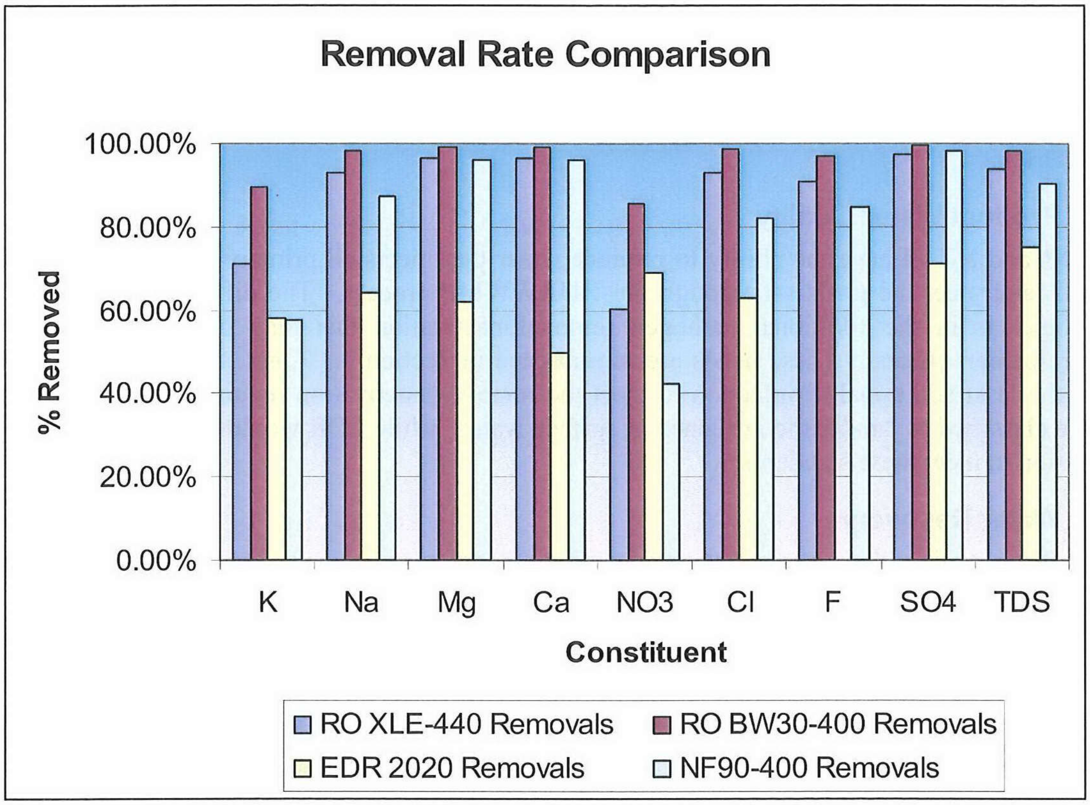
Table 3-9: Water Recovery Comparison Summary

	Reverse Osmosis	Electrodialysis Reversal	Nanofiltration
Water Recovery	75 – 85% (3 stage system)	85 – 94% (2 stack system)	75 – 80% (1 stage system)
Volume of feed water per 1.0 MG of product	1.18 – 1.33 MG	1.06 – 1.18 MG	1.25 – 1.33 MG

3.3.3 Constituent Removal

Removal of dissolved constituents from the feed water is compared based on the percentage reduction in concentration between the feed water and the permeate. Figure 3-5 demonstrates the differences in removal efficiencies between the two RO membranes, EDR and NF based on a single water sample from the San Juan Valley. In general, the BW RO membrane provides the highest removal rates while EDR provides the lower removal rates. For divalent ions, NF achieves removals roughly equivalent to the XLE RO membrane and in many cases similar to those achieved with the BW membrane. The main difference between the two RO membranes is the system pressure, where the higher pressure required for operation of the BW membrane also results in a higher removal efficiency. The physical characteristics of the NF membrane allow for the high removal of divalent ions, which in the Pajaro River Watershed play a large role in actual and perceived potable water quality. Calcium and magnesium are two ions that are highly prevalent in many potable water sources for the Pajaro River Watershed and to counteract the impacts of these minerals, many residents and businesses have installed water softener units on their potable water systems. Removal of the divalent ions from the potable water prior to distribution would provide the basis to begin phasing out the use of home water softeners. Any reduction in water softener use would help the Pajaro River Watershed reduce the importation of salt into the region and would provide an improvement in treated wastewater quality which would reduce future wastewater treatment and disposal costs, and recycled water quality, making recycled water more attractive as an alternative non-potable water supply.

Figure 3-5: Removal Rate Comparison Summary



Note: Removal rates based on analysis performed on a single water sample from the San Juan Valley, exact removals may vary depending on the specific water quality used for feed water. A second sample is planned to be taken to confirm these efficiencies.

3.3.4 Energy Use

A primary consideration in determining the operating costs of any demineralization system is the energy required to separate the dissolved constituents from the water. To characterize this requirement one can analyze the energy input per volume of product water produced as well as the required feed pressure. These data are summarized in Table 3-10 for the three treatment technologies based on the water sample ulitized for this analysis. Each process will require additional energy supplies for ancillary facilities such as chemical feed and product water pumping, however the largest single energy use is typically the driving force for the demineralization process which consists of either high pressure pumps for RO and NF or generation of an electrical gradient for EDR. Overall the NF process appears to require the least energy. However the XLE reverse osmosis membrane requirements are not much greater and other criteria may be required for a true differentiation of energy requirements between these two alternatives. The high energy use of the BW reverse osmosis system can be partially offset through the use of an energy recovery device on the waste concentrate flow stream.

Table 3-10: Energy Use Comparison Summary

	Reverse Osmosis	Electrodialysis Reversal	Nanofiltration
Energy Use (kWh/1,000 gal) [a]	1.45 (XLE system) 2.39 (BW system)[b]	4	1.42
Feed Pressure (psi) [a]	115 (XLE system) 193 (BW system)	< 50	101

Notes:
a – Based on a single water sample from the San Juan Valley. Actual values may change depending on the specific water quality used for feed water.
b - Can be reduced by 10% with the addition of a pressure exchanger device on the waste concentrate stream

3.3.5 Waste Stream Management

Technology selection can influence the options for waste concentrate management due to the variations in the concentration and volume of waste concentrate produced. For the purposes of comparison, RO will be used as the basis to assess the differences between the technologies under consideration. Compared to RO, EDR produces a smaller volume waste material with a lower concentration. This is due to the high water recoveries and relatively low removal efficiencies associated with the process. NF has the potential to produce a smaller quantity of waste material with a slightly lower concentration than RO. Of the three technologies, RO will produce waste material with the largest volume and the highest concentrations. The distinction between waste streams and impact on concentrate management will be discussed in greater detail in Chapter 4.

3.3.6 Pretreatment and Chemical Addition

All demineralization systems are sensitive to the impacts of certain components in the source water. Pretreatment is the common means of mitigating potential impacts to the demineralization process. RO, EDR and NF have similar pre-filtration requirements (cartridge filters) however, chemical requirements differ by process. RO and NF typically require the addition of an anti-scalant to minimize the impact of silica and other dissolved components on the membrane surfaces. EDR does not require this chemical addition because the alternating flow mitigates the impact of any scaling or deposition. Biofouling control will depend on the source water; for most groundwater sources, biofouling is not of concern. If this is identified as a need, chlorine can control the biological growth. EDR membranes have the ability to handle low doses of chlorine in the feed water while RO and NF membranes would require some form of dechlorination, such as injection of sodium bisulfate, to protect the membranes. Overall EDR would require the least extensive pretreatment while RO and NF would require more comprehensive infrastructure and operations. Table 3-11 summarizes the pretreatment and chemical addition requirements for each technology. A pilot testing operation on the specific source water and membrane would be required for RO and NF technologies to determine the optimal anti-scalant for the particular feed water to be used in a full-scale facility. This pilot testing is typically performed just prior to the final design of the demineralization facility.

Table 3-11: Pretreatment and Chemical Addition Summary

	Reverse Osmosis	Electrodialysis Reversal	Nanofiltration
Pre-Treatment	Cartridge filters	Cartridge filters	Cartridge filters
Chemical Addition	Anti-scalant Chlorination Dechlorination	Chlorination	Anti-scalant Chlorination Dechlorination

3.3.7 Post-Treatment and Disinfection

Removal of certain constituents from the source water, such as alkalinity, can result in product water that is corrosive and aggressive. These characteristics require mitigation prior to transmission and distribution to protect the distribution system and customer plumbing. For reverse osmosis and nanofiltration, the typical methods of corrosion control are:

- Degasification (also referred to as decarbonation when carbon dioxide is removed): this process removes dissolved gasses from the product water and provides stabilization
- Blending with other sources: this process can mitigate the corrosive properties of the product water when the blending volumes are sufficient to chemically neutralize the product water characteristics

The operational concept at this stage in planning identifies blending with other water sources as a means to fully supply the water demands, it is assumed that no additional post-treatment is required. This blending is anticipated to occur at two locations: at the treatment facility and within the existing potable water system. At the treatment facility, demineralized water would be blended with untreated groundwater to meet a water quality goal prior to transmission to the distribution system. This blended water would then be further blended in the existing distribution system as it mixes with other sources of potable water such as surface water and other groundwater sources. A specific analysis of the need for degasification is performed in Section 3.4.

In order not to disturb existing distribution system, a condition assessment should be conducted for the distribution system and generate a “demineralization facility water quality guideline”. This water quality guideline will eventually determine the extent of the required post-treatment.

Beyond mitigating chemical properties of the water, additional pathogen removal will be required (as described in Table 3-1) if the source water is designated as “under the influence of surface water”. However, if the source water is not influenced by surface water, these requirements do not apply and the water could be distributed directly following the demineralization process. As for distribution system disinfection, current local groundwater practices do not include chlorine for a residual in the distribution system, but this is an option. Table 3-12 summarizes the post-treatment disinfection requirements in the unlikely event that the source water is considered surface water influenced. Due to the lack of a positive barrier between the source water and the product water, EDR would require substantial additional pathogen removal if the source water is classified as under the influence of surface water. In this source water scenario, RO and NF would require disinfection to meet the virus removal requirements.

Table 3-12: Additional Log Removal Credits Required[a] If Source Water Under the Influence of Surface Water[b]

	Reverse Osmosis	Electrodialysis Reversal	Nanofiltration
Cryptosporidium	0	0.5	0
Giardia Lamblia	0	1.5	0
Virus	2	4	2

Notes:

a – Assumes baseline removals are required and credit is received for aquifer filtration and cartridge filtration (see Section 0.5.2293760 for additional information).

b – If source water is not classified as "under the influence of surface water" then no pathogen removal/inactivation is required

3.3.8 Costs

The final major criterion used to evaluate the three technologies was the cost of each technology. Table 3-13 summarizes the capital and operations/maintenance (O&M) costs for each technology including budget estimates provided by process manufacturers. RO and NF capital costs for the main treatment components are very similar while the EDR cost is significantly higher. This difference is mainly attributed to what specifically is included in the cost quotation for the various processes. The EDR equipment cost estimate includes additional items required for operation of the process, including chemical systems, cleaning systems, engineering assistance, training, testing and other integral elements. In addition, membrane desalination facilities typically have a high operating and maintenance cost. The major element of these costs is energy, although each system has varying labor requirements for cleaning and maintenance/parts replacement. These capital and operations and maintenance cost differentials are addressed and the overall facilities costs are developed in Section 3.4.

Table 3-13: Technology Cost Summary

	Reverse Osmosis	Electrodialysis Reversal	Nanofiltration
Capital Costs	\$350,000 - \$425,000	\$2,060,000	\$475,000 - \$525,000
Major elements not included in quoted costs	Installation Building Piping Chemical facilities Cleaning systems Product water pumps Corrosion control	Installation Building Piping Product water pumps Corrosion control	Installation Building Piping Chemical facilities Cleaning systems Product water pumps Corrosion control
Major Operations and Maintenance (O&M) Cost Issues	Membrane replacement Down-time for cleaning Energy costs Concentrate disposal	Manual membrane cleaning Energy Costs Concentrate disposal	Membrane replacement Down-time for cleaning Energy costs Concentrate disposal

3.3.9 Summary of Comparison

Three technologies, RO, EDR and NF were evaluated based on eight criteria. To qualitatively summarize the results of this analysis, a ranking system is presented below. Table 3-14 defines the symbols used in the comparative ranking of the three technologies.

Table 3-14: Evaluation Ranking Symbols

Ranking Symbol	Meaning
●	Excellent
⭘	Average
○	Poor

The technology alternatives and their relative rankings based on the information shown in this Section are summarized in Table 3-15.

Table 3-15: Technology Evaluation Matrix

Comparison Criteria	Reverse Osmosis	Electrodialysis Reversal	Nanofiltration
Product Water Quality	●	⭘	●
Water Recovery	○	●	⭘
Constituent Removal	●	○	⭘
Energy Use	●	○	●
Waste Stream Management	⭘	●	⭘
Pre-Treatment & Chemical Addition	⭘	●	⭘
Post-Treatment & Disinfection	●	○	●
Cost	●	○	●
Overall	●	○	●

Reverse osmosis and nanofiltration rank as the highest two technologies under consideration based on the criteria used in this technology evaluation. Electrodialysis reversal has several flaws that make this a less than ideal technology for this situation. The major flaws include high energy usage and low constituent removal. Low scores for both of these criteria are manifested as additional risk for the implementation of this technology in terms of operational costs and benefits to the potable water quality. RO and NF both score highly across all of the criteria and no meaningful distinction can be made at this level of analysis. Both RO and NF can provide high quality potable water for the Pajaro River Watershed to assist local water agencies in meeting their potable water and recycled water quality goals. RO and NF will be evaluated on a more detailed present worth cost basis to ascertain which technology will provide the most economical desalination technology for the Pajaro River Watershed.

3.4 Present Worth Economic Evaluation

A present worth economic evaluation provides a more detailed comparison between reverse osmosis and nanofiltration. This evaluation provides conceptual level capital costs and estimates of annual operations and maintenance costs. The basis of evaluation is the production of three million gallons per day (mgd) at 300 mg/L TDS. This is achieved by blending raw groundwater that bypasses the demineralization process with product water from the demineralization process. The blending ratio varies depending on the quality of the product water, which is directly linked to the specific membrane used for the demineralization. Identifying a specific water quality criterion will allow a comparison to be made with imported surface water utilized by a portion of the City of Hollister and Sunnyslope County Water District potable water supply systems.

The cost estimates created for this analysis were developed using the design criteria and unit costs identified in Table 3-16, Table 3-17 and Table 3-18. Cost estimates are based on a set of criteria and unit costs based on May 2007 price levels. The costs presented herein are based on conceptual level engineering and are assumed to be accurate to +50 to -30 percent of the actual cost. Final costs will depend on actual labor and material costs, competitive market conditions, actual site conditions, final project scope, implementation schedule, and other variables.

Table 3-16: Cost Estimate Design Criteria

Criteria/Product	Value/Unit Cost
Groundwater TDS	1,750 mg/L
Intermediate Groundwater Well Yield	250 gallons per minute (gpm)
Deep Groundwater Well Yield	500 gpm
Influent Water Storage	8 hours of influent water needs
Total Blended Water Supply	3.0 mgd (2,085 gpm)
Well operational period	16 hours
Blended Water Storage	1,000,000 gallons
BW Membrane TDS Removal	98.4%
XLE Membrane TDS Removal	94.5%
NF Membrane TDS Removal	90.6%
Membrane System Water Recovery (all)	75%
Number of membranes	168/mgd
Membrane replacement period	3 years
Chemical cleaning period	3 months
Project Contingency	30%
Change Order Contingency	5%
Engineering/Environmental Allowance	20%
Legal/Administrative Allowance	10%
Construction Management Allowance	10%
Facility Life	30 years
Interest Rate	5%
Cost Estimate Reference	May 2007
Cost Estimate Index (Engineering News Record San Francisco Construction Cost Index)	9116.72

Table 3-17: Unit Capital Costs

Criteria/Product	Value/Unit Cost
Land Purchase	$37,600/acre
Storage Cost (cast in place, partially buried covered concrete tank)	$1.72/gallon
Deep Well Development Cost	$700/foot
RO Membrane Unit (BW membranes)	$430,000/mgd
RO Membrane Unit (XLE membranes)	$457,000/mgd
NF Membrane Unit	$510,000/mgd
Decarbonation Units	$134,000/mgd
Membrane Unit Building Cost	$161/sf
Chemical Feed Pumps	$12,900 each
Anti-Scalant Storage Tank (5,000 gal)	$12,900 each
Cleaning Chemical Storage Tank (3,000 gal)	$9,700 each
Pipeline Installation Cost	$8.00/inch diameter/lineal foot
Pipeline Appurtenances	10% of pipeline cost
Concrete	$810/CY
FRP Roof Structures	$43/sf
Pump Stations	$2,700/installed HP (duty + standby)

Table 3-18: Unit Operations and Maintenance Costs

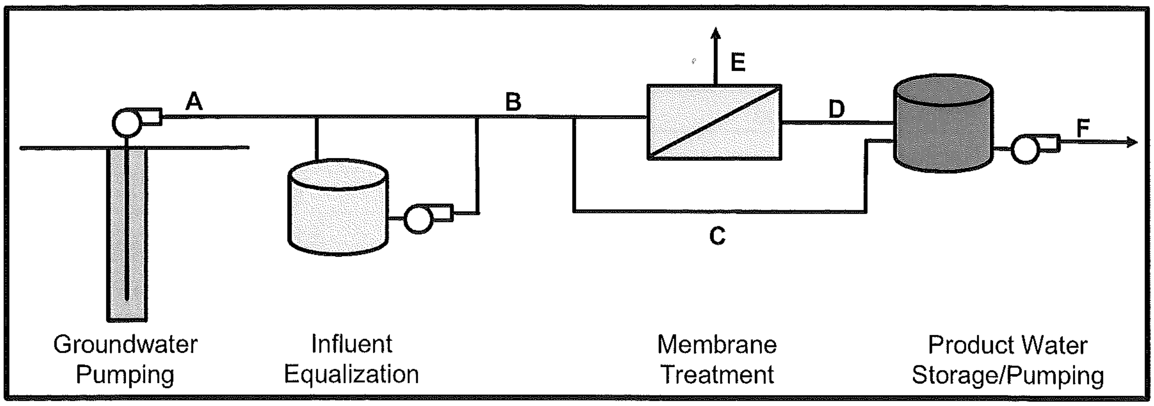
Criteria/Product	Value/Unit Cost
RO BW Membrane Cost	$800/each
RO XLE Membrane Cost	$1,100/each
NF Membrane Cost	$1,200/each
Electricity Costs	$0.15/kWh
Operator Labor	$60/hour
Antiscalant	$0.50/dry lb
Cleaning Chemicals	$4.00/gallon

The present worth cost analysis includes a number of assumptions to provide comparable costs:

- Deep wells will be used for groundwater extraction
- Source water is not surface-water influenced
- Chemical cleaning of membrane units would be staged to minimize storage requirements
- Pump stations would consist of a set of duty pumps and one standby pump to provide reliability
- Concentrate handling is not included in this step of the analysis

The present worth cost analysis was completed for both RO membranes under consideration as well as the NF membrane. The following sections summarize the cost estimates developed for each of these facilities. The flow diagram shown in Figure 3-6 will be used as a general layout for all three estimates and the nomenclature for each piping connection will remain the same as defined in the diagram.

Figure 3-6: General Flow Diagram



3.4.1 BW30-400 Reverse Osmosis System

The BW30-400 reverse osmosis system was developed with the flow conditions summarized in Table 3-19.

Table 3-19: BW30-400 Flow Summary

	Peak Flow (mgd)	Peak Flow (gpm)	TDS (mg/L)	Annual Volume (AFY)
Groundwater Well Capacity (A)	5.8	4,000	1,750	4,300
Facility Influent (B)	3.8	2,670	1,750	4,300
Bypass (C)	0.5	330	1,750	530
Membrane Product (D)	2.5	1,760	30	2,830
Concentrate (E)	0.8	580	6,890	940
Blended Water (F)	3.0	2,080	300	3,360

Table 3-20 summarizes the present worth cost estimate for the BW30-400 RO system. A detailed cost estimate breakdown can be found in Appendix E.

Table 3-20: BW30-400 Present Worth Cost Summary

Item	Cost
CAPITAL COSTS	
Groundwater Extraction/Conveyance	$5,825,000
Demineralization Facility	$8,412,000
Blended Water Transmission	$779,000
RAW CONSTRUCTION COST	$15,020,000
Project Contingency	$4,510,000
Change Order Contingency	$980,000
Engineering/Environmental Allowance	$3,910,000
Legal/Administrative Allowance	$1,950,000
Construction Management Allowance	$1,950,000
TOTAL CAPITAL COST	$28,320,000
ANNUAL OPERATIONS AND MAINTENANCE COSTS	
Consumables	$340,000
Power	$488,000
Labor	$94,000
Chemicals	$53,000
TOTAL ANNUAL O&M COST	$975,000
PRESENT WORTH O&M COST	$14,990,000
TOTAL FACILITY PRESENT WORTH COST	**$43,310,000**

3.4.2 XLE-440 Reverse Osmosis System

The XLE-440 reverse osmosis system was developed with the flow conditions summarized in Table 3-21.

Table 3-21: XLE-440 Flow Summary

	Peak Flow (mgd)	Peak Flow (gpm)	TDS (mg/L)	Annual Volume (AFY)
Groundwater Well Capacity (A)	5.8	4,040	1,750	4,350
Facility Influent (B)	3.9	2,690	1,750	4,350
Bypass (C)	0.4	260	1,750	410
Membrane Product (D)	2.6	1,830	100	2,950
Concentrate (E)	0.9	610	6,620	990
Blended Water (F)	3.0	2,080	300	3,360

Table 3-22 summarizes the present worth cost estimate for the XLE-440 RO system. A detailed cost estimate breakdown can be found in Appendix E.

Table 3-22: XLE-440 Present Worth Cost Summary

Item	Cost
CAPITAL COSTS	
Groundwater Extraction/Conveyance	$5,825,000
Demineralization Facility	$8,578,000
Blended Water Transmission	$779,000
RAW CONSTRUCTION COST	$15,180,000
Project Contingency	$4,550,000
Change Order Contingency	$990,000
Engineering/Environmental Allowance	$3,950,000
Legal/Administrative Allowance	$1,970,000
Construction Management Allowance	$1,970,000
TOTAL CAPITAL COST	$28,610,000
ANNUAL OPERATIONS AND MAINTENANCE COSTS	
Consumables	$386,000
Power	$392,000
Labor	$94,000
Chemicals	$54,000
TOTAL ANNUAL O&M COST	$925,000
PRESENT WORTH O&M COST	$14,220,000
TOTAL FACILITY PRESENT WORTH COST	**$42,830,000**

3.4.3 NF90-400 Nanofiltration System

The NF90-400 nanofiltration system was developed with the flow conditions summarized in Table 3-23.

Table 3-23: NF90-400 Flow Summary

	Peak Flow (mgd)	Peak Flow (gpm)	TDS (mg/L)	Annual Volume (AFY)
Groundwater Well Capacity (A)	5.9	4,070	1,750	4,380
Facility Influent (B)	3.9	2,720	1,750	4,380
Bypass (C)	0.3	180	1,750	290
Membrane Product (D)	2.7	1,900	170	3,070
Concentrate (E)	0.9	630	6,340	1,020
Blended Water (F)	3.0	2,080	300	3,360

Table 3-24 summarizes the present worth cost estimate for the NF90-400 NF system. A detailed cost estimate breakdown can be found in Appendix E.

Table 3-24: NF90-400 Present Worth Cost Summary

Item	Cost
CAPITAL COSTS	
Groundwater Extraction/Conveyance	$5,825,000
Demineralization Facility	$8,842,000
Blended Water Transmission	$779,000
RAW CONSTRUCTION COST	$15,450,000
Project Contingency	$4,640,000
Change Order Contingency	$1,000,000
Engineering/Environmental Allowance	$4,020,000
Legal/Administrative Allowance	$2,010,000
Construction Management Allowance	$2,010,000
TOTAL CAPITAL COST	$29,130,000
ANNUAL OPERATIONS AND MAINTENANCE COSTS	
Consumables	$406,000
Power	$379,000
Labor	$94,000
Chemicals	$54,000
TOTAL ANNUAL O&M COST	$933,000
PRESENT WORTH O&M COST	$14,340,000
TOTAL FACILITY PRESENT WORTH COST	**$43,470,000**

3.4.4 Present Worth Cost Comparison

The present worth costs of the three membrane systems identified in the previous three sections are summarized in Table 3-25.

Table 3-25: Present Worth Cost Analysis Summary

	BW30-400 RO	XLE-440 RO	NF90-400
Total Capital Cost	$28,320,000	$28,610,000	$29,130,000
Annual O&M Cost	$975,000	$925,000	$933,000
Present Worth O&M Cost	$14,990,000	$14,220,000	$14,340,000
Total Facility Present Worth Cost	**$43,310,000**	**$42,830,000**	**$43,470,000**
Annualized Unit Cost ($/AF)	$838	$829	$842
Annualized Unit Cost ($/hundred cubic feet)	$1.92	$1.90	$1.93

Note: Concentrate management and disposal costs are not included in the costs shown

From this summary it is shown that each of the three technology options can produce 3.0 mgd of blended water at 300 mg/L TDS for approximately the same present worth cost, particularly given the level of accuracy of the cost estimate. Additional differences may be realized with the addition of concentrate management costs or with changes in energy or membrane replacement costs. Operations and maintenance costs can be sensitive to fluctuations in market conditions and other external forces and therefore impart a certain level of risk to the implementing agency. For a demineralization system, the major O&M costs are for membrane replacement and energy. Membrane replacement costs are highly dependent on material costs, and since the modern generation of membranes are plastic based, changes in oil prices can have a large impact on membrane costs. Similarly, energy costs are also highly dependent on the costs of oil and in California other market conditions provide additional price volatility. To assess the level of risk associated with each of these technologies based on membrane replacement costs and energy costs a sensitivity analysis was performed on the three options. The annualized unit cost per hundred cubic feet (hcf), not including any concentrate management costs, will be used as the basis to assess the impact of varying these specific O&M unit costs. Table 3-26 summarizes the sensitivity of the unit cost of the water production as it relates to energy costs.

Table 3-26: Energy Cost Sensitivity Analysis ($/hcf)

Variation	BW30-400 RO	XLE-440 RO	NF90-400
Baseline – Energy Cost = $0.15/kWh	$1.92	$1.90	$1.93
Energy Cost = $0.20/kWh	$2.04	$1.99	$2.02
Energy Cost = $0.25/kWh	$2.15	$2.08	$2.10
Energy Cost = $0.30/kWh	$2.26	$2.17	$2.19
Energy Cost = $0.35/kWh	$2.37	$2.26	$2.28
Average $/hcf increase per $0.05/kWh increase	**$0.11**	**$0.09**	**$0.09**

The BW30-400 RO membrane has the highest sensitivity to energy costs while both the XLE-440 and NF90-400 membranes have lower sensitivities. The lower sensitivity corresponds to a lower risk of cost increases due to energy price fluctuations.

Variations in replacement membrane costs can also have a large impact on the annualized unit cost for the production of potable water. Several variations in membrane replacement costs were assessed to determine the impact of the change. Table 3-27 summarizes the unit costs for some identified variations. For each variation, the top cell is the membrane replacement cost and the bottom cell is the unit cost for the potable water produced, not including concentrate disposal costs, in dollars per hundred cubic feet produced.

Table 3-27: Membrane Replacement Cost Sensitivity Analysis ($/hcf)

Variation	BW30-400 RO	XLE-440 RO	NF90-400
Baseline	$800	$1100	$1200
	$1.92	$1.90	$1.93
Reduction in low energy membrane costs	$800	$900	$950
	$1.92	$1.88	$1.91
Universal 15% membrane cost reductions	$680	$935	$1020
	$1.91	$1.89	$1.91
Universal 15% membrane cost increases	$920	$1265	$1380
	$1.94	$1.92	$1.95
Uniform Membrane Costs	$800	$800	$800
	$1.92	$1.87	$1.89

Due to the equal number of membranes proposed for each system, there is little differentiation between the changes for each membrane type when uniform changes are made to the replacement membrane costs.

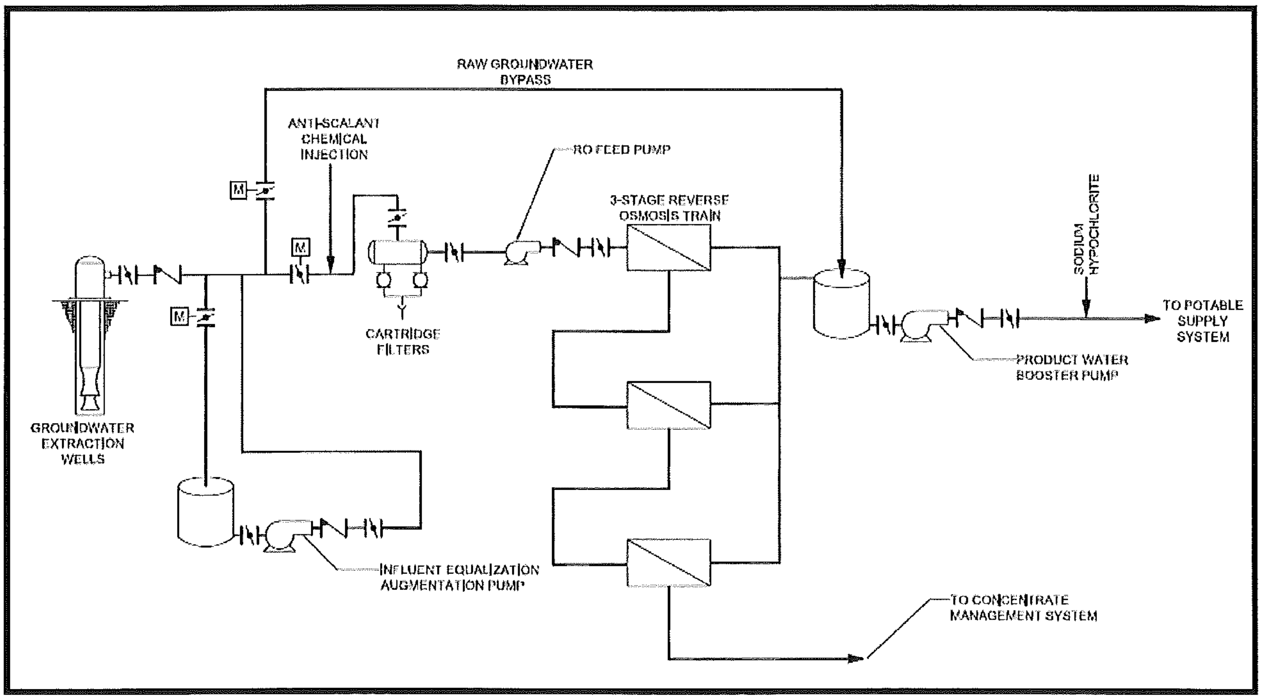
However, one likely scenario is that the replacement cost for the low energy membranes, the XLE-400 and NF90-400, will be reduced as demand for these membranes increases and manufacturing methods continue to evolve and improve.

Based on the sensitivity analysis for energy costs and replacement membrane costs, either the XLE-440 or the NF90-400 membranes would provide a relatively low-risk membrane system for demineralization in the Pajaro River Watershed. The BW40-400 system has higher energy cost sensitivity and therefore imparts an increased risk of cost increases as compared to the other membranes. The final decision on which specific membrane should be used in the Pajaro River Watershed should be delayed until implementation for a project is more imminent so that the specific price conditions can be re-evaluated. For the purposes of this Feasibility Study, costs and design details for the XLE-440 membrane will be used in development of alternatives.

3.5 Demineralization Project Recommendations

As described in previous sections, a demineralization process requires more than just the membrane system. Ancillary systems for influent equalization, cartridge filtration, chemical storage/pumping, product water storage and product water pumping are all potential elements of the overall facility. Figure 3-7 shows the flow schematic representing the major elements of the system.

Figure 3-7: Recommended Process Flow Schematic


RAW GROUNDWATER BYPASS
ANTI-SCALANT CHEMICAL INJECTION
RO FEED PUMP
3-STAGE REVERSE OSMOSIS TRAIN
SODIUM HYPOCHLORITE
M
M
M
TO POTABLE SUPPLY SYSTEM
CARTRIDGE FILTERS
PRODUCT WATER BOOSTER PUMP
GROUNDWATER EXTRACTION WELLS
INFLUENT EQUALIZATION AUGMENTATION PUMP
TO CONCENTRATE MANAGEMENT SYSTEM

The groundwater modeling results, as summarized in Chapter 2, identified 3,000 AFY of additional potable water to be provided from the San Juan Valley to the Hollister Urban Area. Additional potable water could be provided to the City of San Juan Bautista since this would be a direct offset of existing pumping, however due to the pending construction of a surface water treatment plant for the City of San Juan Bautista, this determination would be made at a later date. To produce 3,000 AFY at a constant rate over the course of the entire year would require a blended product water capacity of approximately 1,860 gallons per minute. At a water recovery of 83%, representing an estimate of the water recovered by a 3-stage reverse osmosis system operating on feed water with the characteristics anticipated in the San Juan Valley, the flow distribution between the various fluid pathways is as summarized in Table 3-28. The water recovery used in this analysis is a conservative assumption for a three-stage reverse osmosis system and may be changed following detailed pilot testing of specific membranes on the specific source water for the full-scale demineralization facility. If the concentrate management system provides additional recovered water that could be recirculated to the RO feed flow, the specific flow distributions and TDS concentrations would vary slightly based on that recirculated flow.

This flow summary assumes a groundwater TDS concentration of 1,800 mg/L, an RO product water TDS concentration of 96 mg/L, a blended water TDS goal of 300 mg/L and a 83% water recovery in the RO system. This specific flow distribution does not account for any sustained peaking capacity in the RO system. Peaking capacity beyond the well pumping rates could be accommodated through increases in raw water storage volume and RO system capacity.

The raw groundwater used for blending with the demineralized groundwater may also be supplied via existing groundwater wells in the City of Hollister, assuming a treatment facility location within the City limits. This variation is being investigated by the HUAWWMP as one potential option for the facility operation. The HUAWWMP also identifies the demineralization facility as a centralized facility for the entire Hollister Urban Area, while the design criteria and costs developed in this Study are based on a dedicated facility for the San Juan Valley groundwater source. Final decisions on these two parameters are anticipated to be developed as implementation of the HUAWWMP recommendations occurs over the next several years.

Table 3-28: Recommended RO System Flow Distribution

Description	Flow (gpm)	Flow (AFY)	TDS Concentration (mg/L)
Well Pumping	2,195[a]	3,541	1,800
RO System Influent	1,973	3,182	1,800
Raw Groundwater Bypass	222	359	1,800
RO System Waste Concentrate	335	541	10,105
RO Product Water	1,638	2,641	96
Blended Potable Water	1,860	3,000	300

Notes:
a – With all 7 wells pumping simultaneously, up to 3,500 gallons per minute of water could be provided to the demineralization facility including a portion diverted to the raw groundwater storage tank. Piping for this flow stream will be sized for this peak flow rate. The 2,195 gpm is the minimum required to sustain 2.68 MGD of product water flow.

Table 3-29 summarizes the required sizes of the components of the XLE reverse osmosis system assuming a constant production 1,860 gpm of blended water at 300 mg/L TDS for distribution. Standby equipment is not shown in this summary. Groundwater extraction, groundwater conveyance, waste concentrate management and product water storage/distribution are developed and summarized separately. Key assumptions impacting the sizing of the components are:

- Raw groundwater storage assuming that either four or five wells are pumping at any particular time. Staggering the pumping operation would allow for a smaller raw groundwater storage tank to be constructed and costs for this facility minimized.
- No redundant demineralization capacity
- Five year membrane replacement period
- Decarbonation is required for corrosion control of the RO permeate. Focused pilot testing on the specific source to proof the demineralization facility design parameters would provide specific information on the need for decarbonation of the RO permeate. One potential alternative decarbonation method is to utilize blending with raw groundwater to provide pH buffering capacity to re-establish the carbonate/carbon dioxide balance present in the feed water.

Table 3-29: Reverse Osmosis System Process Sizing Summary

Process	Size or Capacity
Influent Equalization	300,000 gallons
Duty Equalization Return Pumps	2 pumps at 250 gpm, 25 HP each
Demineralization Technology	Low Energy Reverse Osmosis Membranes
Membrane Units (incl. cartridge filters)	5 skids at 0.50 MGD each
High Pressure Pumps	5 pumps at 0.6 MGD, 50 HP each

The cost estimates for the facility described above are based on the criteria and limitations summarized in Section 3.4. The capital costs for this aspect of the demineralization project are escalated to June 2014, the projected mid-point of construction, from the base cost reference of May 2007. The escalation is performed using an inflation rate based on the average annual change in the Engineering News Record San Francisco Construction Cost Index (ENR SF CCI) values between January 1996 (6546.74) and December 2006 (9108.66). Table 3-30 summarizes the capital costs and Table 3-31 summarizes the estimated annual operations and maintenance (O&M) costs for the demineralization treatment aspects of the overall project.

Table 3-30: Demineralization Treatment Capital Cost Estimate

Component	Cost Estimate
Site Work	$419,000
Raw Water Storage	$580,000
Demineralization Equipment & Building	$1,781,000
Chemical Facility	$230,000
Electrical/Instrumentation	$451,000
Raw Construction Cost	**$3,460,000**
Project Contingency (30%)	$1,040,000
Change Order Contingency (5%)	$230,000
Engineering/Environmental Allowance (20%)	$900,000
Legal/Administrative Allowance (10%)	$450,000
Construction Management Allowance (10%)	$450,000
Total Capital Cost (2007)	**$6,530,000**
Annualized Capital Cost (30 year, 5%, 2007)	**$425,000**
Total Capital Cost (2014)	**$8,540,000**
Annualized Capital Cost (30 year, 5%, 2014)	**$556,000**

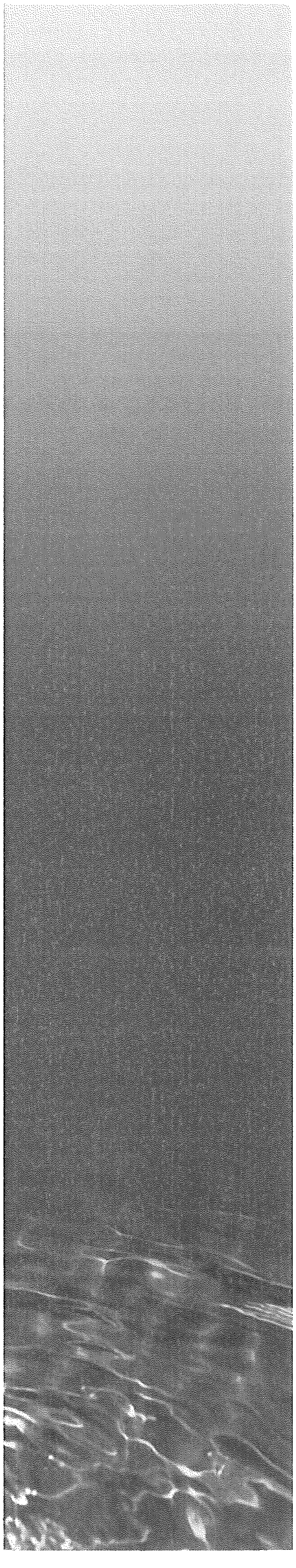
Table 3-31: Demineralization Treatment O&M Cost Estimate

Component	Cost Estimate
Consumables	$141,000
Energy	$163,000
Labor	$69,000
Chemicals	$58,000
Total Annual O&M Cost (2007)	**$430,000**
Present Worth O&M Cost (30 year, 5%, 2007)	**$6,610,000**
Total Annual O&M Cost (2014)	**$560,000**
Present Worth O&M Cost (30 year, 5%, 2014)	**$8,610,000**

3.6 Next Steps

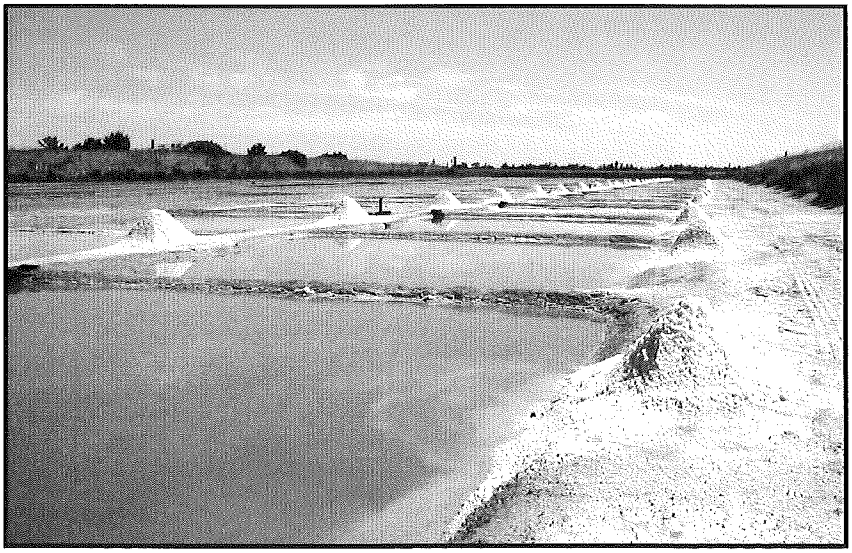
One follow-on step for this project is to develop a preliminary engineering report that would take information developed from other aspects of this Feasibility Study to identify a complete groundwater extraction/demineralization/distribution/concentrate disposal project for the Pajaro River Watershed. For the demineralization aspect of the overall facility, the major additional information to be developed at this future stage would be:

- Location of the treatment facility – dependent on the groundwater source location, the potable water distribution system(s) identified to receive the water and land acquisition considerations
- Size of the treatment facility – dependent on the groundwater pumping operational plan and the identified peak demand to be served by this facility
- Requirements for disinfection – dependent on CDPH determination of the potential contaminating activities in the source water
- Ancillary facilities required for operation – dependent on source water quality and specific membranes to be used in the reverse osmosis system
- Updated full project cost estimate – dependent on all of the additional information developed from this Feasibility Study, including the costs of concentrate management



Chapter Four

Brine Management Assessment



Pajaro River Watershed Groundwater Desalination Feasibility Study

Chapter 4 Brine Management Assessment

4.1 Introduction

Membrane desalination is being evaluated as a treatment technology for high total dissolved solids (TDS) groundwater supplies in the San Juan Valley to remove dissolved constituents from potable water. Disposal of the waste concentrate (often called brine) may pose the most significant challenge in implementing this water resource management application in the San Juan Valley. Regulatory complications, environmental concerns, technological feasibility and public pressures can have significant impacts on the acceptable methods available to dispose of brine from a potential demineralization facility. The available methods are more limited, and therefore typically more costly, for inland locations than for coastal locations due to the lack of a direct ocean outfall for waste concentrate disposal.

This chapter builds on the information developed in the previous chapters to provide the concentrate management analysis that will serve as an additional building block in the development of the overall project. This chapter uses a demineralized product water flow of 1.0 MGD at a water recovery of 83% as the basis for comparison between the identified concentrate management alternatives. The product water flow rate differs from the basis of comparison developed in Chapter 3 to simplify the process comparison and to allow for simplified "scaling up" of the recommended alternative. The final section of this chapter will summarize the specific brine management facilities currently recommended for implementation with the demineralization project identified in previous chapters.

Due to the inland location of the study area, concentrate management has been identified as a significant challenge to the successful implementation of a brackish groundwater demineralization project. The remainder of this chapter will identify the potential concentrate management technologies and develop a recommended concentrate management approach.

4.2 Potential Brine Management Technologies

Table 4-1 identifies the six brine management technologies evaluated as a part of this study and provides a basic description of how each handles the demineralization waste product. These technologies are further described and evaluated in the following sections according to the criteria identified in Section 4.3.

Table 4-1: Brine Management Technology Summary

Technology	End Product & Destination
Evaporation Ponds	Dry solids collected and hauled to landfill
Deep Well Injection	Untreated brine injected into deep well
Disposal to Ocean Outfall	Untreated brine conveyed to ocean
Product Recovery	Selected compounds sold to industry or hauled to landfill
Zero Liquid Discharge	Dry solids collected and hauled to landfill
Vibratory Shear Process	Highly concentrated brine to drying bed; dry solids hauled to landfill

As part of this task, preliminary information was requested from process vendors for each potential technology. The vendors were provided with water quality data from the San Juan Sub-Basin, which was used as the basis for their assumptions, analyses and subsequent estimates. The sample provided to the vendors was extracted from a well in the San Juan Sub-Basin close to the effluent percolation ponds for the City of Hollister Domestic Wastewater Treatment Plant. Due to this proximity of the sampling well to the percolation ponds, it is likely that the water quality data do not accurately represent the conditions present elsewhere in the San Juan Sub-Basin, where potential groundwater extraction facilities are likely to be located. As such, the preliminary product specifications, efficiencies, cost estimates, and other water quality sensitive information provided by vendors may need to be revised based on the results of additional water quality sampling and analysis. Despite the use of this non-representative groundwater sample, the vendor information provides a set of data points that are considered, for the purposes of this chapter, to provide sufficient planning level information for this Feasibility Study.

There is a high probability that no single brine management alternative will provide a complete solution for the Pajaro River Watershed. The final brine management system may be comprised of multiple alternatives identified in this chapter. Through the descriptions of the identified alternatives, potential synergistic relationships can be identified and a preferred brine management system can be recommended.

4.3 Evaluation Criteria

The six technologies under consideration for managing brine in the Pajaro River Watershed were compared using five criteria. The criteria were selected to provide information on all aspects of the treatment technologies and identify the strengths and weaknesses of each. The criteria, described in further detail in the following sections, are:

- Regulatory Considerations
- Technical Considerations
- Water Recovery
- Waste Disposal
- Economic Considerations

4.3.1 Regulatory Considerations

Each brine management process was evaluated with respect to the regulatory requirements that will need to be addressed. Agencies overseeing various aspects of brine management alternatives include the Central Coast Regional Water Quality Control Board (CCRWQCB), the United States Environmental Protection Agency (USEPA) and other resource management agencies depending on the final disposal method for the waste salts. These regulatory considerations may also result in schedule impacts to the project depending on the extent of comments received by the relevant agencies.

4.3.2 Technical Considerations

Technical considerations for the management of the waste brine are divided into design elements and operations & maintenance requirements. Specific design considerations include waste stream characteristics, site requirements, process footprint, sensitivity to deviations from design parameters, suitability for expansion, chemical additions and other relevant process criteria. Anticipated daily and periodic operations and maintenance requirements were also evaluated for each brine management process, including preventive maintenance, chemical feed system maintenance and monitoring, waste product collection, cleaning and other technology-specific needs.

4.3.3 Water Recovery

Several of the brine management processes under consideration are capable of recovering some portion of the liquid fraction of the brine. Additional water recovery benefits the overall system operation by increasing the usable quantity of potable water supply gained from each unit of pumped groundwater. This secondarily recovered water may be of a poorer quality than the demineralization process' product water, and may therefore require recirculation through the demineralization step. This additional step, however, helps minimize the final waste product volume and will therefore reduce the infrastructure and capital and operations costs associated with the final disposal of the removed solids.

4.3.4 Waste Disposal

The ability to cost-effectively dispose of waste from the selected brine management technology is critical to the implementation and success of the overall demineralization process. The evaluation of brine management alternatives included the volume and rate of waste production and the associated benefits and hazards of the disposal methods. One potential limiting factor for the ultimate disposal of the waste product is the concentration of regulated constituents present in the final waste product, such as total dissolved solids or metals in an ocean outfall system. The brine management strategy should therefore be confirmed once the final groundwater supply water quality has been confirmed.

4.3.5 Economic Considerations

One of the most critical aspects of the alternatives evaluation is capital and operations and maintenance costs. The critical economic categories are the capital costs and the recurring operations and maintenance costs, with a focus on energy consumption due to the large variability in energy requirements.

Capital Costs

Cost analyses were conducted using the best available estimates for capital costs of the major process components. The basis of comparison is the costs per one million gallons per day (mgd) of demineralization product water. The primary sources for capital costs are 1) estimates obtained from the major process vendors for each of the technologies, 2) discussions with local agencies about land costs, and 3) discussions with industry professionals involved in similar projects. Final costs will depend on the demineralization process selected, actual labor and material costs, competitive market conditions, actual site conditions, final project scope, implementation schedule, required appurtenant facilities and other variable factors.

Energy and Other Recurring Costs

There are two main types of concentrate management: volume reduction and final disposal. Typically volume reduction, also referred to as advanced concentration, requires energy inputs to remove or recover additional water from the concentrate stream. Depending on the specific technology chosen, this energy can be supplied as fluid pressure, heat or solar radiation. In general, higher levels of concentration are possible with higher energy inputs. With the cost of energy continually rising, this parameter has a significant impact on the facility operating cost and will impact process selection. Final disposal alternatives typically require smaller energy inputs, primarily for conveyance of the concentrate stream.

In addition to energy costs, other major recurring cost elements, such as equipment replacement and waste product disposal costs, were evaluated.

4.4 Technical Evaluation of Brine Management Alternatives

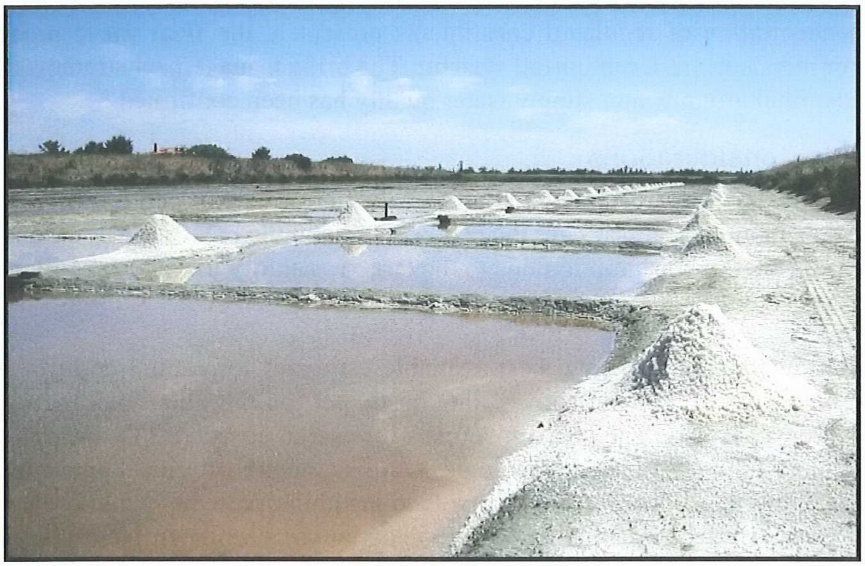
The six brine management alternatives identified in Section 4.2 are described in the following sections. A basic description followed by detailed information pertaining to the identified evaluation criteria are presented to allow for comparative analysis among the alternatives.

4.4.1 Evaporation Ponds

Overview

Evaporation ponds are an available alternative that utilize solar energy to separate water through evaporation from the remaining solids. Evaporation ponds are typically developed as shallow, regulated impoundments for brine containment. Solar energy evaporates the water from the dissolved solids, thereby gradually concentrating the brine and causing solids to precipitate. To prevent infiltration of the brine into the underlying groundwater aquifer, evaporation ponds are typically lined with low-conductivity clay layers, synthetic membranes, or some combination of the two. Solids are periodically removed from the ponds and hauled to a landfill for disposal once the solids have a water content suitable for removal and hauling. This hauling operation permanently removes salt from the local groundwater basin. Frequency of pond "dry-out" and subsequent solid disposal depends on the depth of pond and the concentration of the influent brine. Figure 4-1 shows evaporation ponds in series operation.

Figure 4-1: Evaporation Ponds



Regulatory Considerations

In California, regulatory oversight of evaporation ponds is handled by the applicable RWQCB, in this case the CCRWQCB. For regulatory purposes, evaporation ponds are regarded as surface impoundments. The detailed requirements for surface impoundments can be found in Title 27, Division 2, Subdivision 1, Chapter 3, Subchapters 2 and 3 (Title 27) of the California Code of Regulations (CCR), included in Appendix F

The CCRWQCB requires an Application/Report of Waste Discharge (Form 200, included in Appendix G) to be completed and submitted for approval. It is anticipated that the CCRWQCB would be involved at all levels of planning, design and construction of any evaporation ponds to ensure that the requirements are satisfied. The CCRWQCB may also mandate that a groundwater monitoring program be developed and executed in order to verify non-degredation and protection of the underlying groundwater aquifer.

The California Department of Fish and Game (DFG) may also have regulatory oversight for the pond system as it can be a potential waterfowl habitat. Previous applications of evaporation ponds in the Central Valley have demonstrated high levels of constituents (including selenium) that are problematic to waterfowl. Some level of mitigation, potentially including audible or physical barriers to discourage birds from utilizing the ponds as habitat, may be required.

Technical Considerations – Design Elements

As noted above, evaporation ponds are regarded as surface impoundments in the State of California. As such, they must be designed in accordance with the general regulations governing siting, construction and monitoring of surface impoundments in Title 27 of the California Code of Regulations (CCR), included in Appendix F. The general requirements for evaporation ponds are as follows:

- **Five-Foot Separation**: All new landfills, waste piles and surface impoundments shall be sited, designed, constructed and operated to ensure that wastes will be separated from underlying groundwater by a minimum of five feet.

- **Pond Liner**: Surface impoundments shall have a liner system with a minimum thickness of 40 mils (0.04 inches). Clay can be used if the hydraulic conductivity is less than 1×10^{-6} cm/sec (1 foot/year).
- **Freeboard**: Surface impoundments shall have sufficient freeboard to accommodate seasonal precipitation and a 25-year, 24-hour storm event[8], but at a minimum there shall be no less than 2 feet, measured vertically, from the water surface to the lowest point on the surrounding lined berm or dike. The impoundment shall also be designed and constructed to prevent overtopping as a result of wind conditions likely to accompany such precipitation conditions.
- **Ground Rupture**: Surface impoundments shall have a minimum 200 foot setback from any known Holocene[9] fault. Impoundments can be located within 200 feet of a known fault provided the RWCQB finds that the unit's containment structures are capable of withstanding ground accelerations associated with the maximum credible earthquake.
- **Airport Safety**: If the evaporation pond system is located within 10,000 feet of any airport runway end used by turbojet aircraft or within 5,000 of any airport runway end used by only piston-type aircraft, the pond system must be designed and operated to eliminate bird hazards to aircraft.
- **Ground Water Monitoring**: The CCRWQCB may require the installation of groundwater monitoring wells or monitoring of existing local wells to ensure there is no leakage from the pond system. The monitoring can be greatly reduced or even eliminated through ponds designed for maximum containment.
- **Storage**: The volume of required concentrate storage will vary depending on the total water recovery of the preceding demineralization/brine management system and environmental conditions such as annual evaporation and precipitation. As water recovery increases, the total volume of concentrate for storage and disposal decreases. A water balance model was developed to assess the volume of storage required for varying efficiency values. This model assumes 1) a product water volume of 1.0 mgd, and 2) that the final stage of the evaporation pond system would be implemented as multiple smaller ponds so that the individual ponds could be dried and the solids could be removed with minimal impact to the overall system capacity.

The critical design parameters for an evaporation pond system are the local evaporation and precipitation rates. The critical criteria in determining the required pond size is to determine the evaporation rate in the Hollister area. Two data sources are available for estimating evaporation from ponds in the Hollister area. The first data source uses monthly evaporation from a standard U. S. Weather Bureau Class A (4-foot diameter) evaporation pan tabulated from 1962-1965 by the California Department of Water Resources (1979). For this time period the average evaporation rate was 56.3 in/yr. Lakes have smaller evaporation rates than evaporation pans, especially in arid areas, because the fetch across a lake is long enough to develop a saturated or nearly-saturated boundary layer. Evaporation from lakes can be estimated by multiplying pan evaporation by a pan-to-lake coefficient, which is typically 0.70 to 0.80. Larger coefficients result if the lake is small (for example, a demineralization brine evaporation pond), or the surrounding area is arid (Dunne and Leopold, 1979). A coefficient of 0.8 is reasonable for an evaporation pond in the Hollister area, which corresponds to an annual evaporation rate of 45.0 inches.

The second data source is data from the California Irrigation Management Information System (CIMIS) network of climate stations, one of which is located at the SBCWD offices in Hollister. These stations calculate reference evapotranspiration (ET_0) using an energy-balance approach. Average annual ET_0 at the Hollister station from 1995-2005 was 47.4 inches, which is approximately equal to the estimate of pond evaporation (within the range of uncertainty of the pan-to-lake coefficient). Thus, the CIMIS ET_0

---

[8] CCRWQCB standard. Title 27 of the CCR recommends allowance for a 100-year, 24-hour storm.

[9] A fault that has been active within (approximately) the last 11,000 years.

data may be used directly as an estimate of pond evaporation. The advantage to using CIMIS data is that the climate stations are presently in service and expected to continue operating for the indefinite future, whereas the pan evaporation record consists of only three years in the 1960s.

To determine the annual precipitation, data from 1875 through 2004 were analyzed. Rainfall values prior to June 1995 were obtained from the City of Hollister rain gage while data after that date was collected at the CIMIS station at the SBCWD offices. The annual totals were based on a July to June rainfall "year." The following steps summarize the process used to determine the average rainfall year monthly rainfall distribution:

- Find the average annual total
- Find the average monthly total for each month and the sum of those average monthly values
- Use the average months and their sum to develop a monthly distribution percentage of total annual rainfall
- Apply this monthly percentage distribution to the average annual total to develop the average rainfall year

The monthly average rainfall distribution was developed by scaling the annual average by the monthly contributions based on the percentage distribution of the average month values. Table 4-2 summarizes the average monthly reference evapotranspiration and precipitation data for the Hollister Area. The available storage volume, which is a combination between the depth of the pond and the height of the surrounding berms, must be calculated based on the 25-year, 24-hour storm as specified by the CCRWQCB. The additional rainfall in that year would be accommodated in the storage volume inherent in the ponds, while typical operation of the evaporation ponds would be based on an average rainfall year.

Table 4-2: Monthly Evapotranspiration and Precipitation Rates

Month	Evapotranspiration ET_0 (inches)	Precipitation (inches)
January	1.26	2.49
February	1.69	2.89
March	3.30	3.42
April	4.50	0.83
May	5.82	0.64
June	6.45	0.43
July	6.85	0.00
August	6.24	0.00
September	4.82	0.04
October	3.54	0.07
November	1.70	0.27
December	1.25	3.08
Total	**47.4**	**14.16**

Source: CIMIS Station #126, Hollister Rain Gauge

Table 4-3 shows the variations the evaporation pond area required for concentrate disposal for a product water flow of 1.0 mgd for variations in overall system water recovery.

Table 4-3: Storage Requirements For Varying Water Recoveries and 1.0 MGD of Product Water

Total Demineralization System Efficiency (%)	Required Storage Pond Area (acres)
75 (reverse osmosis minimum)	134
80	100
83 (reverse osmosis design condition)	82
85	71
86	66
87	60
87.5 (reverse osmosis maximum)	57
88	55
89	50
90	45
91	40
92	35
93	30
94	26
95	21
96	17
97	12
98	8
99 (projected upper limit of concentrating technologies)	4

Technical Considerations – Operations & Maintenance Requirements

Day-to-day operations and maintenance (O&M) procedures for evaporations ponds are anticipated to be minimal. Periodic requirements, including drying and the collection/removal of solids, will impact the design by altering the redundancy of the evaporation pond system. In general the pond system would be operated in series with concentrations varying from low to high as the brine passes through the ponds. The final step in this process would need to be comprised of redundant ponds so that individual ponds could be taken out of service for final drying and solids removal. It is assumed that any necessary improvements or repairs to a pond's lining would be conducted immediately following salt removal operations.

Water Recovery

Evaporation ponds, by design, do not recover water from brine. As liquid water in the brine evaporates due to solar warming and wind, water molecules are lost to the atmosphere. The total efficiency of the demineralization-brine management process will not increase with the use of evaporation ponds.

Waste Disposal

Based on a representative water sample from the San Juan Valley, a demineralized product water flow of 1.0 mgd and a water recovery of 83%, approximately 3,150 tons of salt would be removed from the potable water and trapped in the evaporation pond system in a given year. The supporting calculations for this estimate are presented in Appendix H. To maintain the storage capacity in the ponds and to provide salinity benefits for the groundwater basin, this salt will need to be removed and exported for final disposal. The total mass of salts to be removed is also a function of the water content of the final waste product.

Salts can be disposed of at any Class III landfill so long as the salt is classified as a non-hazardous waste. A Class III landfill requires a portion of the landfill is lined to protect the groundwater. Three landfills in the area are suitable for salt disposal.

- Monterey Regional Waste Management District – Marina Landfill
    - Can accept salt anytime throughout the year.
    - Disposal charges range from $41.00 and $66.00 per ton based on the condition of salt.
- Salinas Valley Solid Waste Authority – Crazy Horse Landfill
    - Can only accept salt part of the year because only a portion of the landfill is lined.
    - Disposal charges are $50.00 per ton.
- Salinas Valley Solid Waste Authority – Johnson Canyon Landfill
    - Can accept salt anytime throughout the year.
    - Disposal charges are $50.00 per ton.
    - Can develop a Model Fill at this location. A Model Fill is a private location at the landfill where only its owner can deposit material. The cost (including construction) for an 11 acre Model Fill that can accept salt is approximately $3 million.

Economic Considerations – Capital Costs

Capital costs for evaporation ponds, when considered on a per-unit volume basis, are extremely high. For the valuable agricultural land that is prevalent in the project area, acquisition costs are estimated at $35,000 per acre (2006 costs based on previous local transactions). The supply and installation of a synthetic membrane liner for the ponds is also a major cost. For 1 mgd of product water, a demineralization process water recovery of 83%, and using the guidelines described in Section 4.3 above, approximately 82 acres of evaporation ponds would be required. Table 4-4 summarizes the capital costs associated with the development of evaporation ponds to manage the waste brine for 1.0 mgd of product water. A transmission pipeline for the brine from the treatment facility to the evaporation pond site was included and for comparative purposes, was estimated at a length of 2 miles. Additional equipment and material requirements for evaporation ponds may include yard piping, pumps, environmental impact mitigation facilities and other related equipment and facilities. These additional costs have not been specifically developed at this time and are included as allowances at this stage of alternative evaluation.

Economic Considerations – Energy and Other Recurring Costs

In contrast to the capital costs, energy consumption by an evaporation pond system is estimated to be minimal. The energy required to evaporate water from the concentrate stored in an evaporation pond is solar energy and is not a cost factor. However, the labor and energy required to periodically remove and haul solid waste is not negligible, nor is the effort required to conduct periodic inspections and repairs to the pond itself. Recurring operations and maintenance costs include fuel for solids removal equipment, fuel for disposal trucking and operator time to repair and maintain the pond liner.

The removal of solids from the lined ponds is projected to be similar in effort and cost to the removal of biosolids from a wastewater pond. The Sunnyslope County Water District recently dried several of their wastewater percolation ponds and removed the accumulated solids from the bottom to increase their disposal capacity. This removal and transport process cost approximately $50/wet ton. Due to the care that will be required to protect the pond liner, the removal of dried salts from evaporation ponds has been estimated at twice this unit cost. The disposal fees collected by the landfills are in addition to the removal and transport costs. Assuming that the solids are removed with a water content of 50%, the total removal, transport and disposal cost per dry ton is $300.

Table 4-4 provides an estimate of the costs associated with evaporation pond systems.

Table 4-4: Estimated Evaporation Pond Costs for 1.0 MGD of Product Water

Component	Quantity	Unit Cost	Total Cost
Land Acquisition	90 acres	$37,600/acre	$3,400,000
Pond Liner	3,575,000 SF	$1.07/SF	$3,840,000
Sitework Allowance	1	Lump Sum	$1,120,000
Mechanical/Piping Allowance	1	Lump Sum	$54,000
Environmental Mitigation Allowance	1	Lump Sum	$215,000
Brine Transmission Pipeline (4-inch)	2 miles	$1,065,000/mile	$2,9130,000
Raw Construction Costs			**$10,750,000**
Project Contingency (30%) [a]			$1,970,000
Change Order Contingency (5%) [b]			$470,000
Engineering/Environmental Allowance (20%) [a]			$1,820,000
Legal/Administrative Allowance (10%)			$1,270,000
Construction Management Allowance (10%) [b]			$930,000
Total Capital Costs			**$17,210,000**
Consumables	1	Lump Sum	$25,000
Energy	0	$0.15/kWh	$0
Labor	8 hrs/week	$60/hr	$25,000
Solids Removal, Transport and Disposal	3,150 tons	$300/ton	$945,000
Total Annual O&M Costs			**$995,000**
Present Worth O&M Costs (30 years, 5%)			**$15,300,000**
Total Present Worth Cost			**$32,510,000**

Notes:

a. Applied to 50% of liner costs, plus all other non-land capital costs. 10% contingency added on land capital costs
b. Not applied to land acquisition capital costs

4.4.2 Deep Well Injection

Overview

Deep well injection is the disposal of a liquid waste, in this case waste brine from a demineralization process, at large depths below the ground surface via injection through a deep well. Pressure, provided by a pump at the ground surface, drives the waste brine into voids in the underground geological formation at the bottom of the well. Because injection wells extend to depths far greater than local drinking water aquifers, and terminate below impervious geological formations, the injected material disperses without mingling with drinking water supplies. Typical deep injection wells range from 1,000 to 8,000 feet in depth (Mickley 2004). Typical natural gas wells in the Hollister area range from 3,000 to 8,000 feet deep. The average injection well depth in California is 5,000 feet. Other characteristics of deep injection wells vary significantly, depending on the design flow rate, surrounding geology and previous (if any) use of the well.

Regulatory Considerations

USEPA regulates and monitors all injection well activities. Under the 1974 Safe Drinking Water Act (SDWA), the USEPA established a federal Underground Injection Control (UIC) Program. The UIC established requirements to prevent contamination of Underground Sources of Drinking Water (USDW) as a result of injection well activities. A USDW is defined as an "aquifer or its portion which supplies any public water system or contains a sufficient quantity of ground water to supply a public water system, and either currently supplies a public water system, or contain less than 10,000 milligrams per liter (mg/L) of total dissolved solids (TDS) and is not an exempt aquifer." For a point of reference, the California Department of Public Health (CDPH) has enacted secondary drinking water standards for TDS with a recommended limit of 500 mg/L, an upper limit of 1,000 mg/L and a short-term limit of 1,500 mg/L.

Injection wells are divided into five categories, based on the nature of fluid being injected in proximity to the lowermost USDW. Table 4-5 describes the USEPA classifications.

Table 4-5: USEPA Injection Well Classifications

USEPA Classification	Description
Class I	Wells used to inject waste beneath the lowermost USDW
Class II	Wells used to dispose of fluids associated with the production of oil and natural gas
Class III	Wells used to inject fluids for the extraction of minerals
Class IV	Wells used to dispose of hazardous or radioactive wastes into or above a USDW (Banned in all 50 states unless they are part of a contaminated site cleanup)
Class V	Wells not included in the other classes generally used to inject non-hazardous wastes

An injection well receiving waste brine from a reverse osmosis or similar demineralization process would be classified as a Class I, non-hazardous well. The requirements for the UIC are found in the Code of Federal Regulations (CFR), Title 40: Protection of Environment, sections 124 and 144 through 148. Currently there are five final permits issued through the UIC program by EPA region 9, the region with jurisdiction in California. Table 4-6 summarizes the key information for each of the five final permits.

Table 4-6: EPA Permitted Injection Well Operations

Permittee	Location	Permit Class	Waste Stream	Daily Volume
California Specialty Cheeses	Manteca, CA	Class I	Treated cheese manufacturing wastewater	0.3 MGD
Greka Integrated, Inc	Santa Maria, CA	Class I	Refinery wastewater	None specified
Hilmar Cheese Company	Hilmar, CA	Class I	Treated cheese manufacturing wastewater	2.2 MGD proposed, final volume to be determined after pilot well drilled
City of Los Angeles	San Pedro, CA	Class V (experimental)	Wastewater biosolids	400 tons/day
Puna Geothermal Venture	Pahoa, HI	Class V	Power plant process water	None specified

The CFR outlines injection well requirements, including well construction and well monitoring and reporting. CFR/UIC requirements are summarized below:

- **Well Construction**: The primary construction objective for a Class I Non Hazardous well is to protect the groundwater. This is accomplished by constructing the well using multiple casings and cemented layers designed for the life expectancy of the well and by analyzing the logs during the drilling process.
- **Monitoring and Reporting**: The USEPA requires that the following items for Class I injection wells are continuously monitored and controlled:
  - Analysis of the injection fluid with sufficient frequency to yield representative data of its characteristics.
  - Installation and use of continuous monitoring devises for the following items are required:
    - Injection Rate (gallons per minute)
    - Injection Total Volume (gallons)
    - Injection Pressure (psi)
    - Annular Pressure (psi)
  - A mechanical integrity test at least every five years during the life of the injection well.
    - A well is considered to have mechanical integrity if there are no significant leaks in the casing, tubing or packer and there is no significant fluid movement into a USDW through vertical channels adjacent to the injection well bore.

A quarterly report must be submitted to the USEPA. This report will summarize the analysis of the injection fluid and will identify the average, maximum and minimum monthly values of each of the monitored parameters.

Technical Considerations – Site Selection

Selecting the proper location for a Class I non-hazardous injection well is dependent upon local geologic and hydrogeologic conditions. Two important site selection factors are:

- Water quality at the injection zone, and
- The natural ability of the underground formation to contain the injection fluid.

Prior to design, a detailed study of the potential injection location(s) would need to be conducted in order to determine the capacity and sustainability of the underground formation(s) with respect to disposal and confinement. There are two primary options for deep well injection infrastructure: retrofit an existing oil/gas well or drill a new well in close proximity to an existing well based on information gathered from the existing well. The benefits and drawbacks to both approaches are summarized in Table 4-7.

Table 4-7: Injection Well Siting Alternative Benefits & Drawbacks

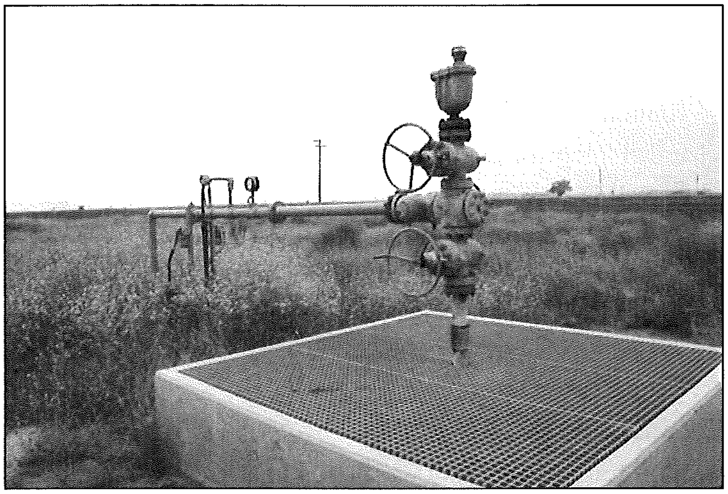
	Benefits	Drawbacks
Retrofit Existing Well	• Minimizes capital costs • Data on subsurface features may exist	• Reduces potential to optimize well characteristics • Minimized potential to upgrade infrastructure
Construct New Well	• Can tune operation to match needs • Can specify infrastructure to meet water quality and operational requirements	• Increased capital cost • May need to rely on inference to develop subsurface characteristics

Hollister and the surrounding areas have a history of natural gas production and the wells used in this production can provide a significant source of data on the local underground conditions. During the drilling of natural gas wells in the Hollister area, soil conditions, including spontaneous potential, resistivity and conductivity, were electronically logged. This data will aid in the evaluation of suitable injection areas.

Technical Considerations – Retrofit of Existing Wells (Case Study)

The County of Santa Barbara Public Works Department – Laguna County Sanitation District (LCSD) is currently using deep well injection to dispose of brine from a wastewater reverse osmosis (RO) process. The well is located in Orcutt, California, approximately six miles from the LCSD wastewater RO facility. The well was originally used to inject oil production water, but had not been used in recent years. Figure 4-2 shows the surface features of the injection well.

Figure 4-2: Example Injection Well (Laguna County Sanitation District)



To meet the current USEPA standards, LCSD was required to upgrade and retrofit the well casing for groundwater protection. Due to significant unforeseen problems with the existing well infrastructure, the well upgrade process proved to be more expensive than expected, and ultimately nearly equaled the cost to construct a new well in approximately the same location.

The well was constructed to a depth of 5,336 feet and is currently permitted to dispose of 200,000 gallons per day with a life expectancy of 30 years. Tests are currently being run on the well in order to update the USEPA permit to increase the well capacity to 1.0 mgd over a life expectancy of 30 years.

Technical Considerations – Operations & Maintenance Requirements

Depending on the characteristics of the brine and the subsurface geology, operational difficulties, including scaling, fouling or plugging, at the brine-soil interface may develop. Mitigation of these problems may require periodic or continual addition of chemicals, as well as periodic monitoring to determine the effectiveness of the measures. These requirements would increase operations and maintenance activities and costs. Pumping of the brine is anticipated to be minimal, approximately 20-feet of added head, due to the high pressure retained in the brine through the RO unit. Monitoring programs would add additional recurring costs also.

Water Recovery

Injection wells do not recover water from brine for additional treatment and beneficial use. The brine is pumped into the well, where pressure gradients and other hydrogeologic conditions will dictate the rate at which the brine diffuses into the surrounding strata. As such, the total efficiency of the demineralization-brine management process will not increase with the use of injection wells.

Waste Disposal

Deep well injection is a final disposal option with no additional waste product requiring disposal.

Economic Considerations – Capital Costs

Capital costs for injection wells include the following components:

- **Feasibility Study**: First, a feasibility study is necessary to determine the suitability of potential well locations and/or existing wells. This type of study would generally include a geologic literature review of the potential injection area, a regulatory and permitting analysis, a technical process summary and an implementation plan including cost estimate and schedule. A potential scope for this type of study can be found in Appendix I.
- **Design**: Once a feasible existing well and/or location for a new well is identified, the next step in the project is to design the injection well facilities and related appurtenances such as transmission piping from the demineralization facility to the well location.
- **Permit Application**: Permit application and negotiations with the USEPA are anticipated to take place concurrently with the design phase.
- **Well Construction**: Well construction or rehabilitation can begin following permitting by the USEPA. Due to the potential of unforeseen circumstances and implementation challenges, construction costs are estimated conservatively. It is assumed that each well will have a life span of 15 years at a flow rate of 1.0 MGD so two wells will need to be constructed to provide 30 years of capacity.
- **Transmission Piping Construction**: For preliminary planning purposes and until sites for the demineralization facility and the injection well have been identified, it has been assumed that two miles of piping would be required from the demineralization site to the injection well site. The estimated capital cost for brine transmission also includes pipeline appurtenances and a potential booster pump station.

Economic Considerations – Energy and Other Recurring Costs

Pumps would consume a majority of the energy used in a deep well injection system. Depending on the demineralization system used and the distance to the injection well, the waste brine may have sufficient pressure to facilitate the injection operation without additional pumping.

Table 4-8 summarizes the major costs for an injection well system.

Table 4-8: Estimated Injection Well Costs for 1.0 MGD of Product Water

Component	Quantity	Unit Cost	Total Cost
Well Construction	2	$2,150,000/each	$4,300,000
Sitework Allowance	1	Lump Sum	$54,000
Brine Pump Station	1	Lump Sum	$54,000
Brine Transmission Pipeline (4-inch)	2 miles	$990,000/mile	$2,130,000
Raw Construction Costs			**$6,530,000**
Project Contingency (30%)			$1,960,000
Change Order Contingency (5%)			$420,000
Feasibility Study			$20,000
Permit Application and Negotiations			$250,000
Engineering/Environmental Allowance (20%)			$1,700,000
Legal/Administrative Allowance (10%)			$850,000
Construction Management Allowance (10%)			$850,000
Total Capital Costs			**$12,580,000**
Consumables	1	Lump Sum	$50,000
Energy	11,100	$0.15/kWh	$1,700
Labor	12 hrs/week	$60/hr	$38,000
Monitoring	1	Lump Sum	$25,000
Total Annual O&M Costs			**$115,000**
Present Worth O&M Costs (30 years, 5%)			**$1,770,000**
Total Present Worth Cost			**$14,350,000**

4.4.3 Disposal to Ocean Outfall

Overview

Final brine disposal may be accomplished via conveyance to an outfall discharging to the Pacific Ocean. Due to varying topography between the Upper Pajaro River Watershed and the Pacific Ocean, a pipeline would likely consist of both gravity and pressure segments. Alternatively, the brine could be conveyed to the ocean using tanker trucks. Upon reaching the ocean, the brine would blend with the receiving seawater in a mixing zone around the outfall discharge.

Regional Ocean Outfall Planning Background

The *Groundwater Management Plan Update for the San Benito County Portion of the Gilroy-Hollister Groundwater Basin* (GMP) was completed in 2003 and describes a program of activities that would result in benefits to the groundwater basin. The associated GMP Environmental Impact Report (EIR) identified several salt management scenarios that were based on exporting salts from the basin.

The ultimate disposal site for salts exported from the San Benito County area in two of these scenarios was the existing ocean outfall for the City of Watsonville Wastewater Treatment Plant (WWTP). This outfall is a 42-inch diameter pipeline that extends 7,350 feet into the Pacific Ocean, terminating with a set of diffuser ports. The depth of the outfall discharge is approximately 64-feet with an initial dilution at the diffuser ports of 84:1 as determined by the State Water Resources Control Board (SWRCB). Two methods were identified for the transport of brine to this facility: 1) truck transportation and 2) a salt export pipeline. Either method could be coupled with a brine management alternative that reduces the overall volume of the waste brine.

The remainder of Section 4.4.3 discusses the feasibility of employing export as a portion of the brine management strategy for this project.

Regulatory Considerations

The Watsonville WWTP currently operates under a set of Waste Discharge Requirements (WDR) and a National Pollutant Discharge Elimination System (NPDES) permit that regulate the concentrations and mass loadings for a variety of wastewater constituents and parameters. Discussions with the City of Watsonville and the CCRWQCB will be required to determine the appropriateness of the existing permit to the addition of brine disposal from the San Benito County area. Several chemical constituents would need to be evaluated in the blended discharge flow (treated wastewater and waste brine) to confirm the blended effluent would meet permit requirements. The cumulative constituents of the water disposed of via the outfall will need to meet these requirements. A summary of the concentration and mass loading requirements from the Watsonville WWTP WDR/NPDES permit is included in Appendix J.

Technical Considerations

The City of Watsonville is currently in the process of implementing a recycled water treatment facility. This facility will divert a large portion of the secondary effluent, currently disposed of through the outfall, during the spring to fall irrigation season for additional treatment and use as agricultural irrigation water. The resulting reduction in flow through the outfall will change the blending characteristics in the outfall and may impose limitations on the quantity of brine that can be disposed of through the outfall while still meeting discharge permit requirements.

For groundwater with an influent TDS concentration of approximately 1,800 mg/L, typical RO facilities produce a waste brine with a TDS concentration of approximately 6,000 to 12,000 mg/L and a volume of approximately 13% to 25% of the influent flow. For comparison, seawater typically has a TDS concentration of approximately 35,000 mg/L. Blending this brine with the City of Watsonville's secondary effluent, with a TDS concentration of approximately 900 mg/L, would bring the discharged TDS concentration closer to that of the natural seawater, potentially assisting in minimizing any impacts to the marine environment caused by freshwater discharge into the ocean.

Technical Considerations – Design Elements: Export Concept 1 – Truck Transportation

Conveyance to the Watsonville WWTP using tanker trucks is one alternative for concentrate export and disposal.

Table 4-9 summarizes the major assumptions for this disposal method for 1.0 MGD of product water.

Table 4-9: Truck Export Design Assumptions for 1.0 MGD of Product Water

Parameter	Value
Product Water Flow	1.0 MGD
Waste Concentrate Flow	17% of feed water
Waste Concentrate Generation	0.20 MGD (constant flow)
Tanker Truck Volume	10,000 gallons
Round Trip Distance	60 miles
Required Trips Per Day	15
Estimated Miles Per Year	328,500
Number of Trips Per Day Per Truck	3
Number of Trucks Required	7
Truck fuel use	6 miles per gallon
Concentrate storage type	Cast-in-place circular concrete tank

Including the costs for truck leasing, fuel, labor, disposal costs, insurance costs and maintenance costs, each truck trip is estimated to cost approximately $1,000. A detailed estimate of the cost per trip can be found in Appendix K. A major cost that will be incurred for this disposal method is the disposal fee charged by the City of Watsonville. Two small demineralization facilities currently dispose of their waste brine at the Watsonville WWTP at a cost of $0.08/gallon. For estimating purposes, it has been assumed that a reduced price of $0.05 per gallon can be negotiated to keep overall disposal costs affordable for the Pajaro River Watershed.

Product water, as well as brine, is planned to be produced at a constant rate requiring some quantity of brine storage, as trucking operations would be restricted to normal working hours at the Watsonville WWTP. Currently, the Watsonville WWTP is staffed between 7:00 AM and 5:00 PM, seven days per week. A minimum of 120,000 gallons of storage would be required per 1.0 MGD of product water to retain the brine produced during the non-operating periods at the Watsonville WWTP. Larger storage volumes may be required to provide additional operational flexibility.

Technical Considerations – Design Elements: Export Concept 2 – Salt Export Pipeline

A pipeline connecting the San Benito County area to a coastal area would provide the most direct means of exporting salt from the groundwater basin. A proposed project by the Pajaro Valley Water Management Agency (PVWMA) includes a pipeline to supply the PVWMA service area with water from the Central Valley Project (CVP). The design of this pipeline is largely complete and the alignment of the pipeline would come within a few miles of the San Juan Valley area. Two alternatives for utilizing this pipeline alignment for salt export are discussed below:

- **Concept 2A – Multi-Purpose Pipeline**

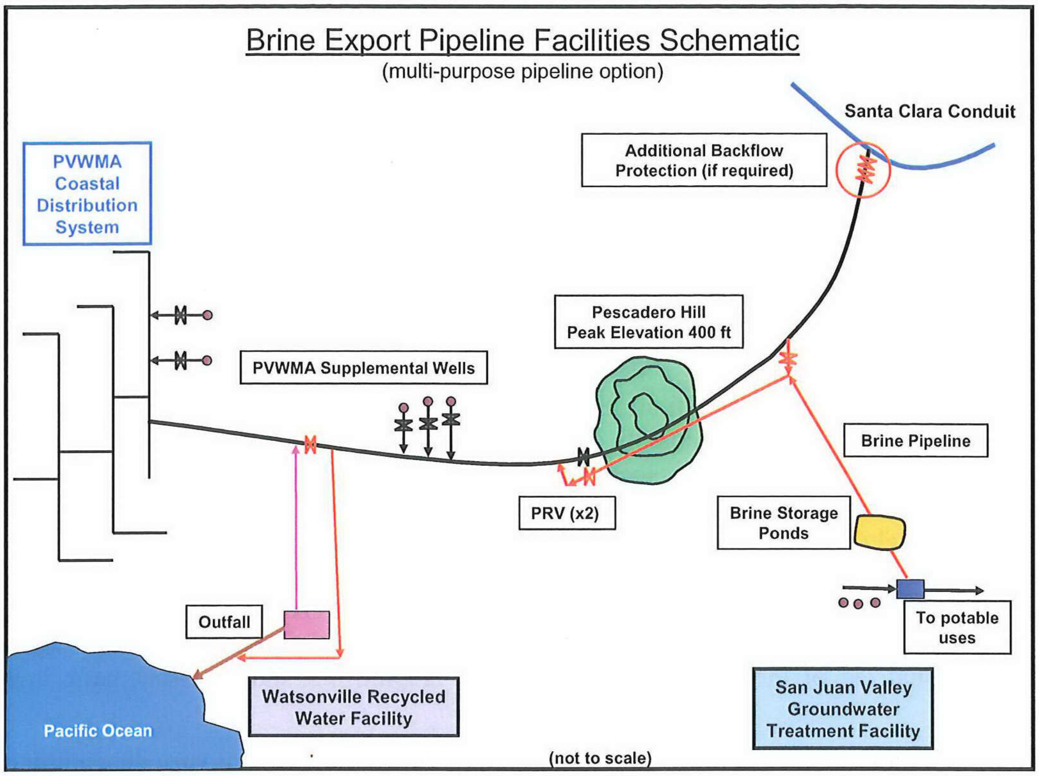
This option would use the planned Pajaro Import pipeline for brine export during the winter months, when Central Valley Project (CVP) water is not anticipated to be delivered to the PVWMA service area and the local groundwater supplies could be used for irrigation purposes. This option would require brine storage during the summer months, when the pipeline will be reserved for the transmission of CVP water, followed by transition to a brine-only flow during the winter months. A bypass pipeline to the Watsonville WWTP would be required to avoid brine entering the irrigation water distribution system. The export system would need to be capable of conveying one year of stored brine during a two- to four-month period. There may be some operational challenges associated with this alternative, given the difference in required pipe diameters for the CVP and brine conveyance. Additionally, the transition between operational periods may require special flushing operations to satisfy permitting and health safety requirements. Backflow protection for the Santa Clara Conduit and the rest of the CVP system would also need to be addressed prior to introducing brine into the CVP system where potable water connections currently exist.

For 1.0 MGD of demineralized product water, approximately 74.8 million gallons of brine will be produced annually, assuming a water recovery of 83%. For the total volume of brine to be conveyed from the San Benito Area to the Watsonville WWTP in a two-month period, an average flow rate of 870 gallons per minute (1.25 mgd) would be required. The volume of brine generated during the non-exporting portion of the year would result in a storage requirement of approximately 62.5 million gallons per 1.0 MGD of product water. A 6-mile transmission pipeline would be required to convey the brine from the San Juan Valley to the nearest point on the PVWMA Import pipeline. The nearest point on the PVWMA Import pipeline, however, is not considered to be the optimum connection point for the brine pipeline, as backflow prevention for the Santa Clara Conduit may be required.

A conceptual method for connecting a Pajaro River Watershed brine pipeline to the PVWMA Import pipeline would be to make a connection downstream of Pescadero Hill. Pescadero Hill is the highest point on the Import pipeline (approximately 400 feet above sea level) which provides a physical barrier to backflow in the Import pipeline. With specific hydraulic operation, the brine could be incorporated into the Import pipeline without any potential for it to overtop the crest of Pescadero Hill. This location would require approximately 9 total miles of brine pipeline with approximately 3 miles of brine pipeline installed parallel to the PVWMA pipeline. Ideally, this 3 mile section of pipe would be installed at the same time as the PVWMA pipeline to minimize construction costs. A pipeline connecting the PVWMA pipeline to the City of Watsonville outfall (an additional one mile of pipe) would need to be constructed to provide the final leg of the brine disposal pipeline. Figure 4-3 shows a schematic layout of this alternative.

Similar to evaporation pond sizing, the volume of required brine storage will vary depending on the total efficiency of the demineralization-brine management system and net evaporation. As efficiency or net evaporation increases, the total volume of brine to be stored, and ultimately disposed of, will decrease.

Figure 4-3: Multi Purpose Export Pipeline Schematic


Brine Export Pipeline Facilities Schematic
(multi-purpose pipeline option)
Santa Clara Conduit
Additional Backflow Protection (if required)
PVWMA Coastal Distribution System
Pescadero Hill Peak Elevation 400 ft
PVWMA Supplemental Wells
Brine Pipeline
PRV (x2)
Brine Storage Ponds
Outfall
To potable uses
Watsonville Recycled Water Facility
San Juan Valley Groundwater Treatment Facility
Pacific Ocean
(not to scale)

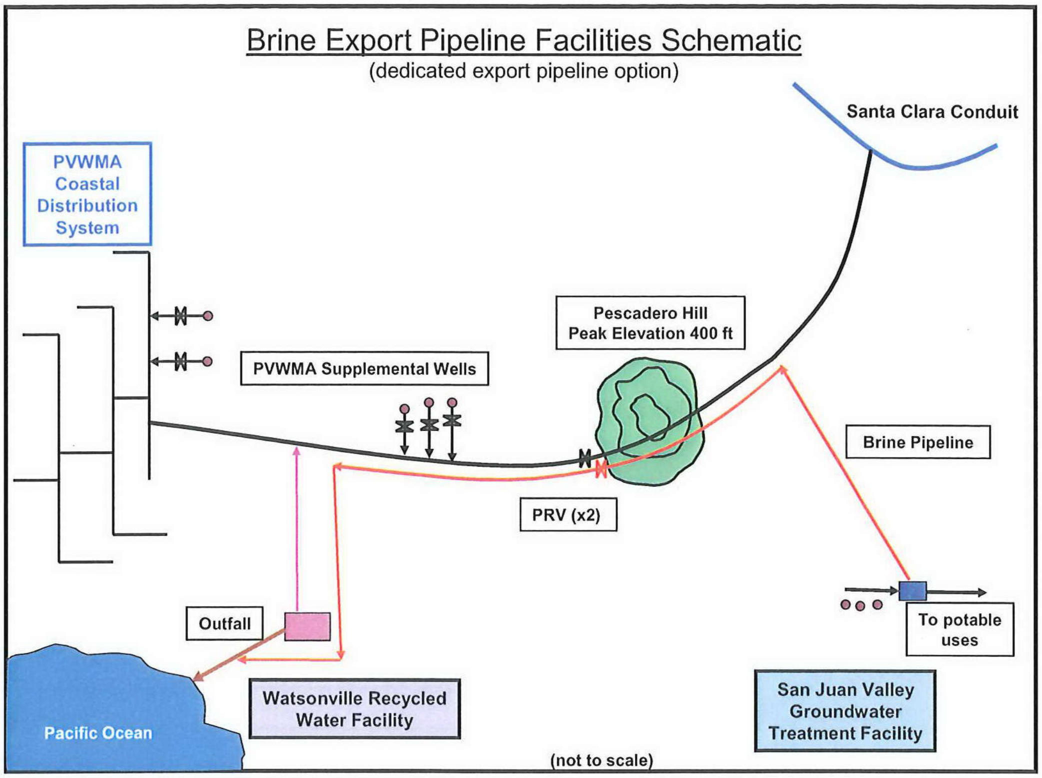
Detailed discussions about the ability of the PVWMA Import pipeline to convey exported brine from the Upper Pajaro River Watershed have not taken place. As more information about potential future export projects becomes available, this alternative may be refined.

Currently, the timeline for construction of the PVWMA Import pipeline is uncertain, imparting a high degree of uncertainty on the availability of this pipe for concentrate disposal. When construction of the PVWMA pipeline is determined, detailed design of the parallel pipeline segment and negotiations to allow multiple uses of the pipeline can begin. Specific requirements for interagency agreements will need to be defined prior to the development of a salt export system for the Upper Pajaro River Watershed.

- **Concept 2B – Dedicated Concentrate Pipeline**

A second option for exporting brine from the San Benito Area involves the construction of a dedicated pipeline to the Watsonville WWTP outfall. Advantages to this option include year-round, permanent disposal capacity for brine and the elimination of significant concentrate storage requirements. For the same annual brine volume, the pipeline would have a smaller diameter as the flow would be constant over the entire year, as opposed to conveying the entire volume over a 2-month period. In addition, a separate pipeline would eliminate issues associated with using the import pipeline for multiple uses, such backflow prevention and seasonal pipeline flushing. The total pipe length is approximately 27 miles. Figure 4-4 shows a schematic layout of this alternative.

Figure 4-4: Dedicated Export Pipeline Schematic


Brine Export Pipeline Facilities Schematic
(dedicated export pipeline option)
Santa Clara Conduit
PVWMA Coastal Distribution System
Pescadero Hill Peak Elevation 400 ft
PVWMA Supplemental Wells
Brine Pipeline
PRV (x2)
Outfall
To potable uses
Watsonville Recycled Water Facility
San Juan Valley Groundwater Treatment Facility
Pacific Ocean
(not to scale)

The optimal method of constructing this pipeline would be to install it in the same trench as the PVWMA pipeline. This method could result in significant cost savings and would allow for economy-of-scale savings during the construction process. The actual cost savings that could be realized with this construction method will be better defined once the Import pipeline is closer to implementation.

Technical Considerations – Operations & Maintenance Requirements

The trucking export option is mainly comprised of operational requirements. These requirements are manifested in truck loading and unloading methods, scheduling, coordination with Watsonville and management of the constructed storage system. Operations and maintenance requirements for either pipeline alternative are anticipated to reflect the requirements for similar transmission pipelines, such as the San Felipe system delivering CVP water to the San Juan Valley.

Water Recovery

Disposal by this method will not provide any direct means of increasing water recovery or efficiency.

Waste Disposal

The City of Watsonville currently accepts brine deliveries from two small drinking water facilities and requirements for these brine deliveries include monitoring, reporting, compliance with a discharge permit issued by the City, and payments to the City for the disposal service. It is assumed that similar requirements will be required for new concentrate discharges, including brine from the San Benito County area; however negotiations with Watsonville may result in lower disposal charges based on cooperation between the two public agencies.

This alternative is a final disposal option with no additional waste product requiring disposal.

Concept 1 Economic Considerations – Capital Costs

Capital costs for the trucking option are primarily for the design and construction of a daily storage facility for the waste brine. Environmental documentation for this project is anticipated to be a larger percentage of the capital costs as a result of the potential coordination and mitigation required for disposal of waste brine into the Monterey Bay Marine Sanctuary. Capital costs for this alternative are shown in Table 4-10.

Concept 1 Economic Considerations – Energy and Other Recurring Costs

The principal energy requirement for the truck transportation alternative is diesel fuel, which is included in the trucking costs in Table 4-10. A large portion of the total annual O&M costs for this concept are the disposal fees assumed to be charged by the City of Watsonville for use of their ocean outfall for brine disposal, which have been assumed to be at a rate of $0.05 per gallon.

Table 4-10: Estimated Brine Trucking Costs for 1.0 MGD of Product Water

Component	Quantity	Unit Cost	Total Cost
Brine Storage Tank	120,000 gallons	$1.90/gallon	$230,000
Earthwork Allowance	1	Lump Sum	$70,000
Mechanical/Piping Allowance	1	Lump Sum	$11,000
Raw Construction Costs			**$310,000**
Project Contingency (25%)			$90,000
Change Order Contingency (5%)			$20,000
Engineering/Environmental Allowance (40%)			$160,000
Legal/Administrative Allowance (10%)			$40,000
Construction Management Allowance (10%)			$40,000
Total Capital Costs			**$660,000**
Consumables	1	Lump Sum	$10,000
Energy	0	kWh	$0
Labor	8 hrs/week	$60/hour	$25,000
Trucking Costs (including disposal fees)	7,480 trips	$1,000/trip	$7,480,000
Total Annual O&M Costs			**$7,515,000**
Present Worth O&M Costs (30 years, 5%)			**$115,520,000**
Total Present Worth Cost			**$116,180,000**

Concept 2A Economic Considerations – Capital Costs

Capital costs for the multipurpose pipeline concept are primarily for the design and construction of 10 miles of pipeline and storage facilities for 62.5 million gallons of brine. However, since this concept is not a viable short-term option, it is assumed that evaporation ponds with sufficient storage were constructed as a near-term management strategy and are available for use as seasonal storage ponds. No additional cost for storage is included in this option. Since capital costs are projected to be large for this option, it is assumed that the pipeline would only be built if a larger regional project is planned. This would result in project cost savings through two avenues:

- Economies of scale present in the installation of a large diameter pipeline
- Installation of a parallel pipeline for portions of the alignment

The pipelines used to convey the waste concentrate are assumed to be combined with waste concentrate conveyance from other regional demineralization projects. To account for this pipeline construction cost savings, the costs for these pipelines are developed as a dedicated pipe for the San Juan Valley only; however the identified costs are then discounted 10% to account for the economies of scale of installing additional capacity in a larger pipe as opposed to a dedicated smaller pipe. Additionally, the three miles of parallel pipeline are assumed to be constructed at an additional 10% discount as compared to the other seven miles. Environmental documentation for this project is anticipated to be a larger percentage of the capital costs as a result of the potential coordination and mitigation required for disposal of waste brine into the Monterey Bay Marine Sanctuary. Additional costs are also identified to support negotiations on institutional agreements between the multiple stakeholders.

Concept 2A Economic Considerations – Energy and Other Recurring Costs

The major recurring cost for the pipeline alternative is the disposal fees charged by the City of Watsonville for the use of the outfall. A disposal fee of $0.05/gallon is assumed for this analysis. Additional recurring costs include labor costs to operate and maintain the storage and piping system and energy costs for pumping the brine through the pipeline. Preliminary system hydraulic evaluations indicate that the brine will need an additional 200 feet of hydraulic head to reach the Watsonville WWTP via the pipe system.

Table 4-11: Estimated Multipurpose Pipeline Export Costs for 1.0 MGD of Product Water

Component	Quantity	Unit Cost	Total Cost
Transmission Pipeline – Parallel Section (8-inch)	3 miles	$1,013,000/mile	$3,040,000
Transmission Pipeline – Separate Section (8-inch)	7 miles	$1,124,000/mile	$7,870,000
Connection at COW WWTP	1	Lump Sum	$54,000
Raw Construction Costs			**$10,950,000**
Project Contingency (25%)			$3,290,000
Change Order Contingency (5%)			$710,000
Engineering/Environmental Allowance (30%)			$4,270,000
Interagency Negotiations			$150,000
Legal/Administrative Allowance (10%)			$1,420,000
Construction Management Allowance (10%)			$1,420,000
Total Capital Costs			**$22,210,000**
Consumables	1	Lump Sum	$50,000
Energy	47,100	kWh	$7,100
Labor	20 hrs/week	$60/hour	$63,000
Disposal Fees	74,800,000 gal	$0.05/gal	$3,740,000
Total Annual O&M Costs			**$3,860,000**
Present Worth O&M Costs (30 years, 5%)			**$59,340,000**
Total Present Worth Cost			**$81,550,000**

Concept 2B Economic Considerations – Capital Costs

Capital costs for the dedicated pipeline concept are primarily for the design and construction of 27 miles of pipeline. The pipelines used to convey the waste concentrate are assumed to be combined with waste concentrate conveyance from other regional demineralization projects. To account for this pipeline construction cost savings, the costs for these pipelines are developed as a dedicated pipe for the San Juan Valley only; however the identified costs are then discounted 10% to account for the economies of scale of installing additional capacity in a larger pipe as opposed to a dedicated smaller pipe. Additionally, the three miles of parallel pipeline are assumed to be constructed at an additional 10% discount as compared to the other seven miles. Additional costs are also identified to support negotiations on institutional agreements between the multiple stakeholders.

Concept 2B Economic Considerations – Energy and Other Recurring Costs

The major recurring cost for the pipeline alternative is the disposal fees charged by the City of Watsonville for the use of the outfall. A disposal fee of $0.05/gallon is assumed for this analysis. Additional recurring costs include labor costs to operate and maintain the piping system and energy costs for pumping the brine through the pipeline. It is assumed that the brine will need an additional 200 feet of head to reach the Watsonville WWTP via the pipe system.

Table 4-12: Estimated Dedicated Pipeline Export Costs for 1.0 MGD of Product Water

Component	Quantity	Unit Cost	Total Cost
Transmission Pipeline – Parallel Section (4-inch)	20 miles	$860,000/mile	$17,190,000
Transmission Pipeline – Separate Section (4-inch)	7 miles	$960,000/mile	$6,690,000
Connection at COW WWTP	1	Lump Sum	$54,000
Raw Construction Costs			**$23,920,000**
Project Contingency (25%)			$7,180,000
Change Order Contingency (5%)			$1,560,000
Engineering/Environmental Allowance (20%)			$6,220,000
Legal/Administrative Allowance (10%)			$3,110,000
Construction Management Allowance (10%)			$3,110,000
Total Capital Costs			**$45,100,000**
Consumables	1	Lump Sum	$150,000
Energy	47,100	kWh	$7,100
Labor	20 hrs/week	$60/hour	$63,000
Disposal Fees	74,800,000 gal	$0.05/gal	$3,740,000
Total Annual O&M Costs			**$3,960,000**
Present Worth O&M Costs (30 years, 5%)			**$60,870,000**
Total Present Worth Cost			**$105,970,000**

4.4.4 Product Recovery

Overview

In the context of brine management, product recovery refers to any process by which marketable products can be selectively recovered from the waste brine from a demineralization process. To date, there are relatively few applications of product recovery technologies in the United States. More significant applications are present in the Middle East and Australia, where seawater desalination is more widespread than in North America. Product Recovery is still a developing concept and is not mature enough for cost estimation and project implementation.

Depending on the specific demineralization process and the constituents present in the feed water, certain constituents in the brine can be separated for reuse or specialized disposal. The resulting compounds may have some commercial value or may need to be removed to simplify disposal of the final waste product.

The following compounds represent a sample of those that can potentially be recovered or produced from waste demineralization brine:

- Gypsum-Magnesium hydroxide compound, $CaSO_4 \cdot 2H_2O + Mg(OH)_2$

- Magnesium hydroxide, $Mg(OH)_2$
- Sodium chloride, NaCl
- Sodium sulfate, Na_2SO_4
- Calcium chloride, $CaCl_2$
- Precipitated calcium carbonate (PCC), $CaCO_3$

The compounds listed above can be used in the production of a variety of industrial and agricultural products, including:

- Animal dietary needs
- Fire retardants
- Manufacture of magnesium metals
- Manufacture of light-weight and fire-proof plaster boards
- Manufacture of salt-tolerant building footings, wall panels, and other construction products
- Applications in food and chloralkali industries
- Tannery applications
- Production of quality paper products
- Manufacture of plastics, paints, ink, and sealant products
- Soil conditioners for remediation of sodic and acidic soils
- Sealants for irrigation channels and earthen ponds
- Premium stabilizers for road base construction
- Flocculating agents for water/wastewater treatment
- Dust suppressant

In addition to beneficial products, the product recovery systems can remove constituents that could complicate final disposal of the waste product such as heavy metals, volatile organic compounds and other organic contaminants. None of these constituents are anticipated to be a concern for this application.

Regulatory Considerations

Specific regulatory oversight of a product recovery process is not anticipated; however the overall brine management system may include a variety of components including storage, concentration and disposal elements. These components may be subject to regulatory oversight as described previously for the other potential brine management technologies in this chapter.

Technical Considerations

Due to a lack of representative water quality samples, much of the technical evaluation of the product recovery systems is at the conceptual stage. These systems are very sensitive to variations in the feed water quality and the operation of these systems will necessarily vary depending on the actual water quality encountered. If product recovery is identified as an element in the overall brine management system, detailed evaluations of the projected feed water and brine quality will be required to properly select and configure this component.

Lawrence Livermore National Laboratory (LLNL) conducted a desktop feasibility evaluation of selectively precipitating salts from the waste brine to assist in removing salt from the Pajaro River Watershed. This evaluation was based on anticipated brine chemical characteristics and performed using computer software developed by LLNL for similar evaluations. Additionally, LLNL conducted a bench-scale test of their Field Induced Charge (FIC) Membrane process which can extract constituents of interest from the brine. Representative groundwater samples from the San Juan Valley were provided to LLNL for the purpose of concentrating to approximate brine characteristics and ultimately for use in testing the FIC process. The efficiency and energy requirements for this step were evaluated in the context of achieving a minimum of one of three goals: 1) extraction of selected components for commercialization, 2) removal of selected constituents of concern to allow for brine disposal where sensitivity to certain components may exist, and 3) an increase in product water recovery, minimizing the quantity of liquid brine for disposal.

The main results from this work identified that due to the kinetic order of likely precipitates, there were no economically beneficial solids that could be harvested from the waste brine. The primary precipitate is aragonite, which is a crystal variant of calcite. Calcite has value in concrete production while aragonite, due to the specific crystalline structure, is not a valuable product. Additionally, their modeling and testing identified that at the recommended water recovery for a reverse osmosis process (83%) arsenic and uranium may be concentrated in the waste brine to levels that exceed regulatory limits. These constituents will need to be specifically sampled for in the brine during the specific pilot testing that will need to be performed prior to project implementation. Increased water recovery through the FIC process will be limited due to the saturation levels of certain constituents in the waste brine and their tendency to precipitate. Some additional conclusions from the LLNL work included:

- pH adjustment as pretreatment may assist in control of carbonate scaling but may exacerbate the formation of silica compounds
- Carbon dioxide concentrations in the permeate water due to carbonate removal or precipitation may be significant and could require post-treatment to mitigate the concentrations to avoid effervescence
- Reductions of magnesium and/or sulfate concentrations in the feed water may allow calcite to precipitate instead of aragonite, resulting in a potential marketable by-product from the RO treatment process

The complete LLNL testing report is attached as Appendix L.

There are several other companies that provide product recovery services for municipal and industrial waste streams. Geo-Processors, Inc. (GP) is a global company based in Australia that specializes in the recovery of constituents from concentrated brine flows. GP has developed several proprietary product recovery technologies for product recovery applications including SAL-PROC and ROSP (Reverse Osmosis in conjunction with SAL-PROC). The SAL-PROC process is the heart of GP technologies, and it involves sequential reaction and evapo-cooling steps, causing a variety of compounds to precipitate and crystallize from waste brine. Certain reactions for product formation are facilitated by the addition of reagents. Depending on the characteristics of the brine, implementation of an ROSP process could result in a zero liquid discharge condition, eliminating the need for substantial liquid disposal facilities. To date, SAL-PROC installations are primarily located in Australia with other investigations underway in the Middle East. GP is in the process of assessing the feasibility of product recovery technologies for agencies near Denver, Colorado and Las Vegas, Nevada. Evaluation of the relevant GP options may be a future stage of the project and would require water quality analysis for the specific well locations to be developed in the San Juan Sub-Basin.

4.4.5 Zero Liquid Discharge

Overview

Zero liquid discharge (ZLD) processes are brine treatment methods that eliminate liquid from the waste stream. The end product of a ZLD process is a solid or near-solid substance that will require disposal in a landfill or other solid waste facility. Due to the inland location of the Upper Pajaro River Watershed, the elimination of liquid discharges from the demineralization process would provide a variety of operational, maintenance, and economic benefits, by eliminating disposal of any liquid waste and associated construction, transportation, conveyance and final disposal costs.

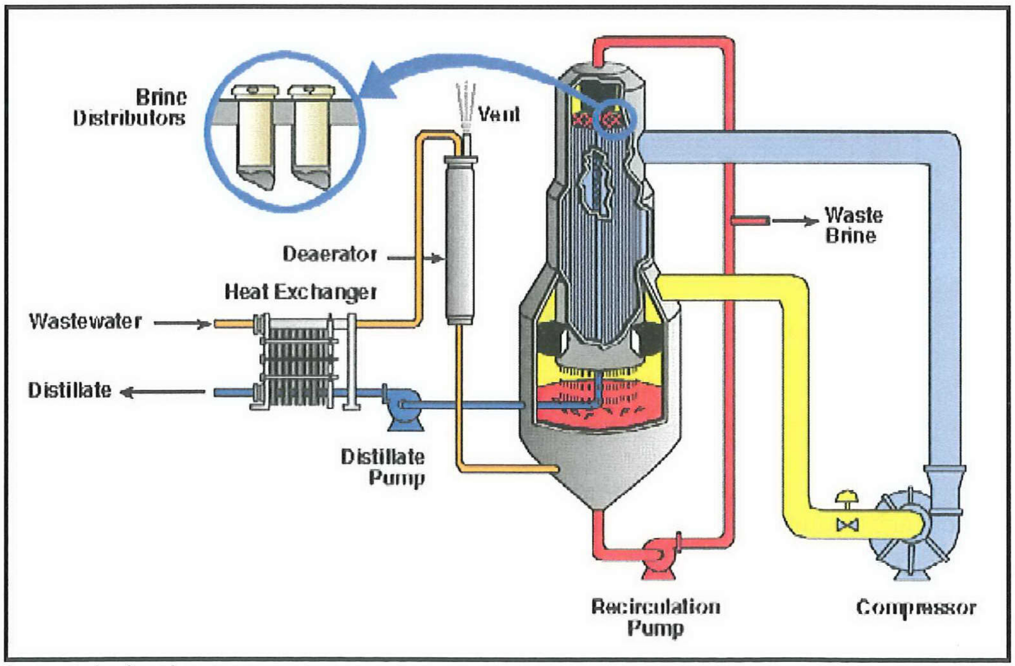
In the simplest ZLD configuration, waste brine would be treated through some combination of 1) brine concentrators/evaporators, 2) evaporation ponds and 3) brine crystallizers. Distilled water from the concentrator or crystallizer steps could be recirculated to the demineralization process for additional treatment. The solid end products would be collected and transported to a landfill for disposal.

Brine concentrators and brine crystallizers are described in further detail below.

- **Brine Concentrator / Evaporator**

A brine concentrator, or evaporator, is often the first step in a ZLD process. Although there are different types of brine concentrators, this evaluation focuses on seeded slurry vapor compression evaporators such as the system produced by GE Ionics, Inc. In vapor compression evaporators, the influent brine enters a heat exchanger, where the brine is heated to near boiling. The heated brine then passes through a deaerator, where steam strips non-condensable gases such as carbon dioxide and oxygen. The heated and deaerated brine then enters a sump, where it is combined with a recirculating slurry of concentrated brine. To maintain salt suspension, the slurry is typically seeded with small crystals of calcium sulfate that provide an adhering surface for precipitating salts. The slurry is pumped from the bottom of the sump to the set of heat transfer tubes, over which the brine is distributed evenly. As a film of slurry travels down the sides of the tubes, a portion of the water evaporates. After traveling down the tubes with the slurry, the vapor is drawn into a vapor compressor. By being passed along the outside of the heat transfer tubes, the vapor transfers its latent heat to the brine slurry and begins to condense. The resulting distillate is pumped back through the heat exchanger, where remaining sensible heat is recovered by the incoming feed brine. To control the density of the evaporator atmosphere, a small amount of brine slurry must be continuously released from the evaporator. Depending on its purity, distillate from the brine concentrator may be recirculated to the demineralization process, or may be stored with product water (Heins, 2004). Figure 4-5 shows the main aspects of the brine evaporator process.

Figure 4-5: Vapor Compression Evaporator



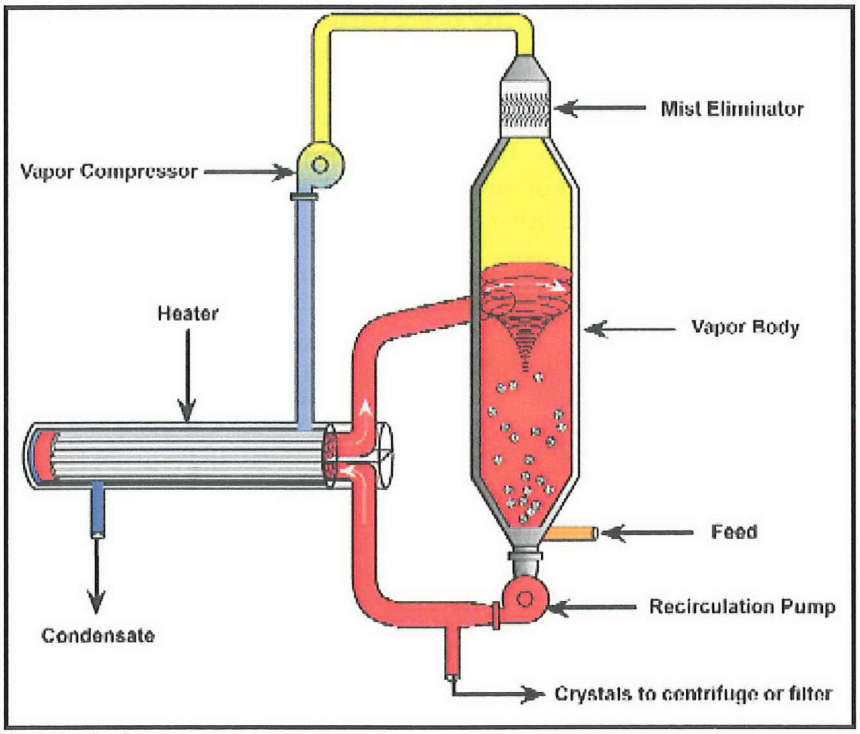
Source: Ionics, Inc.

- **Brine Crystallizer**

The brine crystallization process is typically the second step in ZLD systems. A solids crystallizer can be used in lieu of an evaporation pond, although all three ZLD processes could potentially be combined depending on the specific economics of the application.

A brine crystallizer reduces concentrated brine to a very thick slurry waste product. Although there are several types of solids crystallizers, this evaluation focuses on vapor compression cycle crystallizers, which are typically more energy efficient than other varieties in moderate-to-large flow applications. In a vapor compression crystallizer, influent brine from a brine concentrator enters a vapor body containing brine slurry. A recirculating pump at the bottom of the vapor body pumps the slurry to a heater. Prior to reaching the heater a slipstream is drawn from the slurry into a solids separation device, typically consisting of a centrifuge or an automatic pressure filter. The slurry reaching the heater is heated to a high temperature, and then flashes into the vapor body again and creates a vortex. Water evaporating from the slurry is drawn through a mist eliminator into a vapor compressor (typically a positive displacement rotary blower), which then passes the compressed vapor into the shell of the heater, where its heat is transferred to the recirculating slurry. The resulting condensate may be recycled to the demineralization process or stored with product water (Griffin, Schooley and Solomon, 2004). Figure 4-6 is a schematic of a typical vapor compression solids crystallizer.

Figure 4-6: Vapor Compression Solids Crystallizer



Source: Ionics, Inc.

The solid cake produced by the solids separation unit usually contains between 5 and 10 percent moisture, is easy to handle and is suitable for landfill disposal.

- **Evaporation Pond**

Evaporation ponds can be used in a ZLD process as a replacement for or supplement to the brine concentration step. The main benefit to using an evaporation pond in this process is the reduction in energy costs. See Section 4.4.1 for information on evaporation ponds.

Regulatory Considerations

Although there are generally no specific permits that must be obtained for operation of ZLD facilities, disposal of solids from a ZLD system would be regulated like other non-hazardous solid wastes. Specific attention would need to be made to trace contaminants, metals and radionuclides. Refer to Section 4.4.1 for more information on disposal of non-hazardous salts.

Technical Considerations – Design Elements

Brine concentrators and brine crystallizers are sensitive to deviations from their design parameters, particularly the quality of the influent brine. To avoid inefficient operation and increased maintenance requirements, changes in the flows or loads from the design conditions should be minimized. Furthermore, brine crystallizers are very sensitive to organic antiscalants often used as RO pretreatment to avoid fouling of RO membranes. If organic antiscalants are used in front of a ZLD system that was designed without considering the chemicals, severe foaming problems can result. Individual considerations for brine concentrators and crystallizers are summarized below:

- **Brine Concentrator / Evaporator**: Depending on the chemical characteristics of the brine, reagents such as sulfuric acid, caustic soda and anti-foaming agents may be required to prevent scaling, foaming and other operational complications.
- **Brine Crystallizer**: Foaming, scaling, corrosive environments, and shifts in boiling point temperatures are all considerations that must be addressed during design of a mixed salt solids crystallizer.

In the absence of representative water quality samples and final decisions on demineralization process details, technical design considerations specific to this Feasibility Study have not been developed at this time.

Technical Considerations – Operations & Maintenance Requirements

Operations and maintenance requirements are highly dependent on the influent brine characteristics and the presence of chemicals and other reagents that may be introduced upstream of the ZLD system. The most significant requirements involve the maintenance of chemical feed systems and the variety of heating and pumping equipment. As a practical matter, operations and maintenance may be time-consuming if water quality is anticipated to fluctuate.

Water Recovery

Assuming that the end product of a ZLD system (that does not include evaporation ponds) would be a solid cake of low moisture content, virtually all water could be recovered from the overall demineralization-brine management process. The distillate from the brine concentrator could be recirculated to the demineralization process for additional treatment prior to distribution.

Waste Disposal

The solid cake would be disposed of at a landfill with similar requirements and costs as developed for solids removed from evaporation ponds (see Section 4.4.1).

Economic Considerations – Capital Costs

Because the configuration of a ZLD system is highly dependent on accurate source water quality samples, which may be highly dependent on the specific location of the groundwater well and the specific demineralization process implemented, capital cost estimates for a ZLD system are not presented at this time.

Economic Considerations – Energy and Other Recurring Costs

- **Brine Concentrators**: Approximately 80 kWh are consumed for every 1,000 gallons of influent brine. 80-90% of total ZLD energy requirements are consumed by the brine concentrator (L. Weimer, personal communication, August 2006).
- **Brine Crystallizers**: Approximately 150 kWh are consumed for every 1,000 gallons of concentrated brine from the brine concentrator. Typically, only one gallon of brine is fed to a brine crystallizer for every 40 gallons of brine fed to a brine concentrator (L. Weimer, personal communication, August 2006).

4.4.6 Vibratory Shear Processes

Overview

The Vibratory Shear Enhanced Process (VSEP) is a membrane filtration process that applies torsional vibration to the membrane surface. The shear waves resonating from the membrane surface act to hold suspended particles above the membrane surface, allowing free transport of the liquid media through the membrane. The primary result of VSEP is the delivery of energy to the membrane surface effectively so that fouling formation is disrupted and minimized, which generally eliminates the need for pretreatment and anti-scalant chemicals. The primary purpose of this process is to increase overall system water recovery and decrease the volume of brine requiring final disposal. The process is capable of producing overall system recovery rates approaching 99% (Y. Chang, personal communication, September 19, 2006).

The VSEP membrane filter pack consists of flat sheet membranes, arrayed as parallel discs and separated by gaskets. The disc stack resembles records on a record changer, with a membrane on each side. The disk stack is oscillated above a torsion spring that moves the stack back and forth approximately 7/8 inches (2.22 centimeters). This motion is analogous to the agitator of a washing machine, but occurs at a speed faster than can be perceived by the human eye.

VSEP is currently being used in food processing, chemical, and oil industries. VSEP is not well-established in the groundwater or water treatment industry, but a pilot system is operating in California treating brine from a brackish groundwater demineralization facility.

Laboratory-scale testing of the VSEP system on a representative sample of groundwater from the San Juan Valley is recommended and can be provided by the vendor for approximately $2,000. The results produce guidelines, criteria and information on the capabilities and costs for a VSEP system operating on the specific groundwater planned to be used for a full-scale demineralization facility.

Regulatory Considerations

Specific regulatory oversight of the VSEP process is not anticipated; the overall brine management system, however, may include a variety of components including storage, concentration and disposal elements. These components may be subject to regulatory oversight as described previously for the other potential brine management technologies in this chapter.

Technical Considerations – Design Elements

New Logic Research Inc. (New Logic) patented the VSEP technology and is the only manufacturer of this type of membrane filtration process. The VSEP system does not use specialized membranes and can operate using virtually any type of membrane typically used in water treatment processes including reverse osmosis, nanofiltration, ultrafiltration or microfiltration. Due to the reduction in fouling potential, VSEP systems operate may using membrane flux rates greater than that typically used in reverse osmosis.

Technical Considerations – Operations & Maintenance Requirements

As with any piece of vibrating or spinning mechanical equipment, proper adjustments and tuning are very important to the proper operation of the unit. New Logic has developed a detailed daily, weekly and monthly inspection and maintenance schedule. When done properly, most inspection and maintenance work is reported to take approximately 10 minutes.

Maintenance of the membranes used in the VSEP unit varies depending on the application. On average a chemical cleaning is required one to two times a week. This process is completely automated and controlled through the integrated process control system and takes approximately two hours to complete.

Water Recovery

Water recovery for a complete demineralization facility utilizing VSEP units is estimated to range between 95 and 99%, and higher recoveries can potentially be achieved depending on the quality of the brine. Specific estimates of actual recovery potential will be developed as part of the laboratory-scale testing planned for this brine management technology. An overall water recovery of 98% will be assumed.

Waste Disposal

The waste stream from the VSEP process will require management using the same methods as brine from a typical membrane treatment process. The increased water recovery realized through the use of this process will significantly reduce the volume of brine for final disposal. The concentration of this final waste will be increased, potentially requiring additional design and operational considerations.

Economic Considerations – Capital Costs

In the absence of reliable water quality samples, VSEP was able to provide only a preliminary capital cost data, summarized in Table 4-13. Based on proposals submitted for other similar projects, costs for the VSEP process can vary significantly depending on the specific water quality situation. These variations will be better defined once testing of the VSEP system on project-specific groundwater is completed. For the purposes of this study, the preliminary cost estimate obtained from VSEP was used in the absence of other specific data. The need for a building to enclose the VSEP units may also be required based on the specific environmental conditions, however building costs are not included in this evaluation.

Energy and Other Recurring Costs

The VSEP system, like other membrane processes, is an energy intensive process. High pressure booster pumps are the main energy uses for the system. The weekly or semi-weekly cleaning cycles require chemicals that need to be stored on-site and replenished. Likely one of the largest costs associated with the VSEP system is the periodic replacement of the membranes in the filter pack. The membranes have an estimated life of 3-5 years and an estimated replacement cost of $80,000 per filter pack. The filter packs are complete units and can not have portions replaced. The annual O&M costs developed for this system assume a 5 year replacement cycle for the filter packs. This replacement is both material and labor intensive due to the configuration of the filter pack.

Table 4-13: Summary of Estimated VSEP Costs for 1.0 MGD of Product Water

Component	Quantity	Unit Cost	Total Cost
VSEP Equipment	150 gpm	$3,870,000	$3,870,000
Earthwork Allowance	1	Lump Sum	$54,000
Mechanical Allowance	1	Lump Sum	$161,000
Electrical Allowance	1	Lump Sum	$269,000
Raw Construction Costs			**$4,350,000**
Project Contingency (25%)			$1,310,000
Change Order Contingency (5%)			$280,000
Engineering/Environmental Allowance (20%)			$1,130,000
Legal/Administrative Allowance (10%)			$570,000
Construction Management Allowance (10%)			$570,000
Total Capital Costs			**$8,210,000**
Consumables (non membranes)	1	Lump Sum	$50,000
Membranes	1.2 per year	$80,000/each	$96,000
Energy	94,100 kWh	$0.15/kWh	$14,200
Labor	16 hrs/week	$60/hour	$50,000
Chemicals	1	Lump Sum	$15,000
Total Annual O&M Costs			**$225,000**
Present Worth O&M Costs (30 years, 5%)			**$3,460,000**
Total Present Worth Cost			**$11,670,000**

Impact of VSEP on Other Alternatives

Increasing the water recovery of the overall demineralization system from 83%, assumed for three-stage RO, to 98% will result in large changes in the design capacity of whichever final disposal method is implemented. The following sections summarize the difference in cost for the evaporation pond, the deep well injection and the three export alternatives assuming that a water recoveries increase by 15% through the use of a VSEP system.

The increased efficiency results in a decrease in brine volume from 0.20 MGD to 0.02 MGD per 1.0 MGD of product water produced. This reduction in brine volume will have impacts on the overall costs of each brine management alternative previously discussed. In addition to the cost savings that will be realized by the reduction in the brine volume, the increase in water recovery will result in increased water supply as the recovery of an additional 180,000 gallons per day (24,200 cubic feet per day) of water can be distributed with no increase in groundwater pumping volumes. Table 4-14 shows the economic benefits of this additional water recovery on annual water rate revenue. It should be noted that these additional water revenues could result in nearly $3.5 million in offset present worth costs over a 30-year period. Due to the uncertainty in the specific performance of the VSEP system, these offset costs are not included in the comparative tables but would represent a large portion of the annual VSEP operations and maintenance costs.

Table 4-14: Revenue Impacts of VSEP Operation

	83% Recovery	98% Recovery
Groundwater Pumping	1.20 MGD	1.20 MGD
Product Water	1.00 MGD	1.18 MGD
Annual Product Water	487,970 hundred cubic feet	576,160 hundred cubic feet
City of Hollister Water Price	$2.57/hcf	$2.57/hcf
Annual Revenue	$1,254,080	$1,480,720
Revenue from Additional Recovery	-	$226,640

- **Evaporation Ponds**

The required area for evaporation ponds is reduced from 82 acres to 8 acres with an increase in water recovery from 83% to 98%. Corresponding decreases in capacity and required investment for the sitework, mechanical work, transmission pipeline and environmental mitigation result in additional cost savings. Table 4-15 compares the costs for an evaporation pond system with and without additional water recovery using a VSEP unit. Overall the addition of a VSEP unit provides approximately $1,510,000 in cost savings over the assumed 30-year life cycle.

Table 4-15: Evaporation Pond Cost Savings for 1.0 MGD of Product Water

	83% Recovery	98% Recovery
Raw Construction Cost	$10,750,000	$2,490,000
Total Capital Cost	$17,210,000	$4,390,000
Annual Evap Pond O&M Costs	$995,000	$972,000
Present Worth O&M Costs	$15,300,000	$14,940,000
Total Evaporation Pond Present Worth Costs	$32,510,000	$19,330,000
Total Present Worth VSEP Costs	$0	$11,670,000
Total Present Worth Brine Management Costs	**$32,510,000**	**$31,000,000**

- **Deep Well Injection**

The major difference for the deep well injection brine management alternative is the need to only construct one injection well as opposed to two. The reduction in volume of the brine produced would likely increase the projected life of the well thereby eliminating the need for a second well. Corresponding savings for sitework, pumping and the brine transmission pipeline were also determined. Table 4-16 compares the costs for a deep well injection system with and without additional water recovery using a VSEP unit. Overall the addition of a VSEP unit does not provide cost savings for the deep well injection brine management option and this combination of brine management options will not be economically viable unless there are technical or permitting obstacles to constructing and operating two injection wells.

Table 4-16: Deep Well Injection Cost Savings for 1.0 MGD of Product Water

	83% Recovery	98% Recovery
Raw Construction Cost	$6,530,000	$3,650,000
Total Capital Cost	$12,580,000	$7,170,000
Annual O&M Costs	$115,000	$75,000
Present Worth O&M Costs	$1,770,000	$1,150,000
Total Deep Well Injection Present Worth Costs	$14,350,000	$8,320,000
Total Present Worth VSEP Costs	$0	$11,670,000
Total Present Worth Brine Management Costs	**$14,350,000**	**$19,990,000**

- **Brine Export Concept 1 – Truck Transportation**

The operation of a trucking option for brine export would be significantly impacted by the implementation of the VSEP process. The number of required truck trips per day would decrease from 21 to 3 with an annual decrease in trips from 7,480 to 745. This reduction results in significant savings in annual costs for this option. Table 4-17 compares the costs for brine export using tanker trucks with and without additional water recovery using a VSEP unit.

Table 4-17: Brine Export via Trucking Cost Savings for 1.0 MGD of Product Water

	83% Recovery	98% Recovery
Raw Construction Cost	$310,000	$80,000
Total Capital Cost	$660,000	$170,000
Annual O&M Costs	$7,515,000	$778,000
Present Worth O&M Costs	$115,520,000	$11,960,000
Total Brine Export via Trucking Present Worth Costs	$116,180,000	$12,130,000
Total Present Worth VSEP Costs	$0	$11,670,000
Total Present Worth Brine Management Costs	**$116,180,000**	**$23,800,000**

- **Brine Export Concepts 2A and 2B – Pipeline Export**

By far, the largest cost component for either pipeline export option was the disposal fees to use the outfall at the Watsonville WWTP. By reducing the volume of brine, these annual costs decrease dramatically. It should be noted that pipeline costs shown for these options are based on a very small pipeline diameter and may not scale directly into the larger size pipeline which would be required for facilities producing more than 1.0 MGD of product water. The costs are, however, developed to be comparable between the multiple options being examined. Table 4-18 and Table 4-19 summarize the substantial cost savings associated with the multipurpose and dedicated brine export pipeline options with the addition of VSEP units.

Table 4-18: Brine Export via Multipurpose Pipeline Cost Savings for 1.0 MGD of Product Water

	83% Recovery	98% Recovery
Raw Construction Cost	$10,950,000	$7,460,000
Total Capital Cost	$22,210,000	$15,190,000
Annual O&M Costs	$3,860,000	$554,000
Present Worth O&M Costs	$59,340,000	$8,520,000
Total Multipurpose Pipeline Present Worth Costs	$81,550,000	$23,710,000
Total Present Worth VSEP Costs	$0	$11,670,000
Total Present Worth Brine Management Costs	**$81,550,000**	**$35,380,000**

Table 4-19: Brine Export via Dedicated Pipeline Cost Savings for 1.0 MGD of Product Water

	83% Recovery	98% Recovery
Raw Construction Cost	$23,920,000	$16,040,000
Total Capital Cost	$45,100,000	$30,240,000
Annual O&M Costs	$3,960,000	$634,000
Present Worth O&M Costs	$60,870,000	$9,750,000
Total Dedicated Pipeline Present Worth Costs	$105,970,000	$39,990,000
Total Present Worth VSEP Costs	$0	$11,670,000
Total Present Worth Brine Management Costs	**$105,970,000**	**$51,660,000**

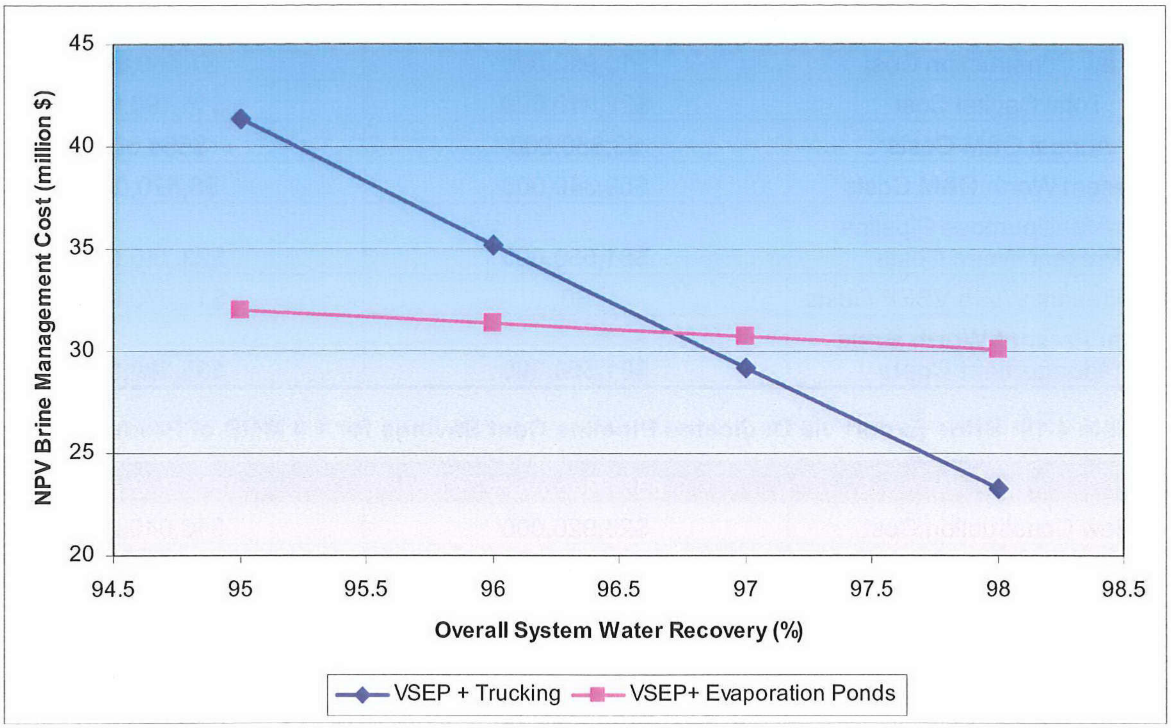
The VSEP process is not a final disposal mechanism but would facilitate final disposal through volume minimization. Of the several final disposal options under consideration (evaporation ponds, deep well injection, truck export and pipeline export) evaporation ponds and truck export make the most economic sense to pair with the VSEP process. Based on an overall water recovery of 98%, truck export is the most economically viable alternative to pair with VSEP, however if the 98% water recovery is not achieved, significant costs will be incurred for the trucking alternative. Reductions in the overall water recovery could be a function of source water variations, process upsets or mechanical complications. To assess these impacts on the VSEP/trucking and VSEP/evaporation pond options, a sensitivity analysis was performed to determine the degree of cost variation for each of these two options based on changing water recoveries. Figure 4-7 summarizes the results of this analysis. This shows that the VSEP/trucking alternative is significantly more sensitive to the overall system water recovery than the VSEP/evaporation pond alternative is.

Additionally trucking operations have other inherent risks including:

- Transportation interruptions due to weather or labor conflicts
- Dependence on other agencies for a critical element of the demineralization project with no additional flexibility
- Increased traffic and the associated public safety concerns

Due to the high degree of risk incurred through the trucking operation, the VSEP/evaporation pond alternative will be carried forward as the recommended VSEP brine management option.

Figure 4-7: Water Recovery Impacts on Brine Management Costs



4.5 Comparison of Brine Management Alternatives

Seven potential brine management alternatives (six were identified in Section 4.2 and brine export was broken into two distinct options) were evaluated based on the five criteria presented in Section 4.3. To qualitatively summarize the results of this analysis, a ranking system is presented below. Table 4-20 defines the symbols used in the comparative ranking of the seven alternatives.

Table 4-20: Evaluation Ranking Symbols

Ranking Symbol	Meaning
●	Excellent
⭘	Average
○	Poor

The brine management alternatives and their relative rankings based on the information developed through this section are summarized in Table 4-21.

Table 4-21: Brine Management Alternative Evaluation Matrix

Comparison Criteria	Evaporation Ponds	Deep Well Injection	Brine Export – Trucking	Brine Export – Pipeline	Product Recovery	ZLD	VSEP + Evap
Regulatory Considerations	⭘	○	○	○	●	●	●
Technical Considerations	●	INC	○	⭘	○	○	⭘
Water Recovery	○	○	○	○	⭘	●	⭘
Waste Disposal	○	●	●	●	⭘	⭘	⭘
Economic Considerations – Capital Costs	○	⭘	●	○	INC	INC	⭘
Economic Considerations – Other Recurring Costs	⭘	●	○	○	INC	INC	⭘
Overall	⭘	⭘/ INC	○	○	⭘/ INC	⭘/ INC	●

INC – Incomplete Evaluation

Of the seven alternatives that were evaluated for brine management in the Pajaro River Watershed, three require more detailed evaluation based on specific brine quality information or local hydrogeologic conditions. These three alternatives have specific steps that are required to generate the information needed to complete their analysis.

- Deep well injection will require the completion of a site selection feasibility study to provide a preliminary assessment of the potential for this brine disposal method to be implemented in the Pajaro River Watershed.
- Product recovery will require the consideration of the results from the LLNL research (report included as Appendix L) about the Field Induced Charge membrane process that has the ability to selectively remove compounds from a liquid brine stream. Additional information from GeoProcessors may also be beneficial based on new water quality analyses that are representative of conditions for the specific wells to be used as sources for the demineralization facility.
- Zero liquid discharge will require specific details on the demineralization process and the exact quality of the source water to better define the costs associated with constructing and operating a ZLD facility.

The remaining four alternatives can be divided into potential near-term elements, potential long-term elements and non-viable solutions. The VSEP process and evaporation ponds both are viable near-term brine management alternatives and lend themselves to a combined strategy. Brine export via a pipeline to the Watsonville WWTP outfall is a potential long-term option when assumed to be constructed in conjunction with the proposed Import pipeline to the PVWMA service area. Brine export via trucking will impose substantial operational constraints on the brine management system and would have a large operational cost that would provide minimal benefit to the Upper Pajaro River Watershed. A potential brine management implementation strategy based on this evaluation is presented in the following section.

4.6 Brine Management Implementation Strategy

Based on available technical and economic data on the brine management options described above, and on the evaluation criteria described earlier in Section 4.3, the recommended strategy is a combination of VSEP and evaporation ponds as the recommended near-term option for implementation in the Pajaro

River Watershed. An alternative near-term option would be deep well injection, pending the results of a feasibility analysis and other technical development. Long-term management options, such as pipeline export, could be developed to augment the VSEP/Pond Management strategy. The following section summarizes this recommendation for the sizing of the recommended facility for demineralization in the San Juan Valley. This recommended facility builds on the recommendations from Chapter 2 and Chapter 3. The facility will be required to manage 0.48 MGD of influent brine produced as the by-product of the demineralization of 2.34 MGD of product water.

4.6.1 Joint VSEP/Evaporation Pond Brine Management Strategy

Rapid Implementation

The technical feasibility of using VSEP can be reasonably assured, and there are no significant permitting issues associated with the process. Evaporation ponds are technically feasible, and in conjunction with the VSEP system would be greatly reduced in areal extent. This reduction in required land area is anticipated to be obtainable and the permitting process duration slightly reduced, as compared to the permitting requirements for the lower recovery rates, based on the lower land requirements. Construction of evaporation ponds is a relatively straightforward venture with a focus on earthwork and no major mechanical facilities.

High Efficiency

With a combined water recovery of 95-99%, the VSEP system would maximize the benefit of each unit of groundwater extracted and would minimize the required waste brine handling facilities.

Low Capital Costs

Based on the preliminary cost data available, it appears that the capital costs for a VSEP facility and the associated evaporation ponds are comparable to or less than the capital costs for the other options.

Table 4-22, Table 4-23, Table 4-24 and Table 4-25 summarize the design criteria, the basis for the cost estimate, the capital costs and the annual O&M costs associated with the VSEP-evaporation pond system based on the maximum yield from the groundwater basin (presented in Chapter 2) and the associated recommended sizing of demineralization facilities (presented in Chapter 3). This facility would manage and dispose of 0.48 mgd of concentrate from 2.34 mgd of product water production.

Table 4-22: VSEP with Evaporation Pond Sizing Summary

Process	Size or Capacity
VSEP Capacity	350 gallons per minute
VSEP Filter Packs	14 filter packs, 25 gpm each
VSEP Effluent Piping	4-inch diameter, 2 miles
Evaporation Pond Area	20 acres

The cost estimates for the facility described above are based on the criteria and limitations summarized in the previous chapter. The capital costs for this aspect of the demineralization project are escalated to June 2014, the projected mid-point of construction, from the base cost reference of May 2007. The escalation is performed using an inflation rate based on the average annual change in the Engineering News Record San Francisco Construction Cost Index (ENR SF CCI) values between January 1996 (6546.74) and December 2006 (9108.66).

Table 4-23: Cost Estimate Development Criteria

Element	Value/Unit Cost
VSEP Cost	$645,000 per 25 gpm
Land Acquisition	$37,600/acre
Pond Liner	$1.10/SF
Brine Transmission Pipeline (4-inch)	$500,000/mile
Consumables (equipment, mechanical, electrical, instrumentation)	2% of capital cost
Electricity Costs	$0.15/kWh
Operator Labor	$60/hour
Cost Estimate Reference	May 2007
Cost Estimate Index (ENR SF CCI)	9116.72
Annual Inflation Rate (average annual ENR SF CCI increase over past 10 years)	3.9%

Table 4-24: Brine Management Capital Cost Estimate

Component	Cost Estimate
VSEP Equipment	$9,020,000
VSEP Site/Mechanical/Electrical	$1,020,000
Evaporation Pond Land Acquisition	$830,000
Evaporation Pond Development	$1,570,000
Brine Transmission Pipeline	$1,000,000
Salt Removal Equipment	$269,000
Raw Construction Cost	**$13,710,000**
Project Contingency (30%) [a]	$3,810,000
Change Order Contingency (5%) [b]	$830,000
Engineering/Environmental Allowance (20%) [a]	$3,330,000
Legal/Administrative Allowance (10%)	$1,750,000
Construction Management Allowance (10%) [b]	$1,670,000
Total Capital Cost (2007)	**$25,100,000**
Annualized Capital Cost (30 year, 5%, 2007)	**$1,633,000**
Total Capital Cost (2014)	**$32,810,000**
Annualized Capital Cost (30 year, 5%, 2014)	**$2,134,000**

Notes:

a. Applied to 50% of liner costs, plus all other non-land capital costs. 10% contingency added on land capital costs

b. Not applied to land acquisition capital costs

Table 4-25: Brine Management O&M Cost Estimate

Component	Cost Estimate
Consumables	$421,000
Energy	$33,000
Labor	$75,000
Chemicals	$43,000
Salt Disposal (6,241 tons)	$1,872,000
Total Annual O&M Cost (2007)	**$2,445,000**
Present Worth O&M Cost (30 year, 5%, 2007)	**$37,590,000**
Total Annual O&M Cost (2014)	**$3,195,000**
Present Worth O&M Cost (30 year, 5%, 2014)	**$49,110,000**

4.6.2 Other Feasible Brine Management Alternatives

Three alternatives may provide additional project benefits and incur fewer project costs than a VSEP process coupled with evaporation ponds. One option, deep well injection, could be a viable near-term alternative disposal method pending the results of a feasibility analysis and additional technical evaluation. The permitting process for this option is thought to be reasonable and a permit for this operation could be obtained based on recent EPA actions. The second option, pipeline export, may provide a long-term disposal method to remove salts from the groundwater basin. The third alternative, product recovery, could allow the facility to generate additional revenue to offset capital and operational costs.

The implementation of the identified near-term brine management alternative (VSEP/Evaporation Ponds) is not anticipated to technically or institutionally preclude implementation of any of the other three potential management options at a later date. The use of VSEP and evaporation ponds would potentially provide several benefits to additional management systems and would function as a building block for these systems.

- Reduction of volume through the VSEP/evaporation pond system would reduce the sizing of any additional management systems
- For deep well injection, a portion of the evaporation pond area could be sold to help in offsetting the project cost
- For pipeline export, the evaporation ponds could function as storage ponds if a dedicated pipeline was not available for brine export
- For product recovery systems, the VSEP/evaporation pond system would provide additional concentration upstream of the process that may enhance the operation of the systems

Near Term Alternative: Deep Well Injection

Depending on the outcome of additional investigation and/or potential feasibility studies, deep well injection may provide added benefits to the project partners. A successful deep injection well with a long useful life eliminates many brine handling and disposal requirements, a possibility that may result in significant cost savings over the life of the project. Additionally, construction and operation of a deep injection well may be less expensive than estimated, and therefore more attractive from an economic standpoint. Other potential benefits include:

- Implementation is under local control and not dependent on significant coordination with other regional agencies
- Operational flexibility

- Reduced capital investment if existing well(s) found to be suitable
- Minimal operations and maintenance costs
- Near-term brine management plans, including VSEP and evaporation ponds, could be used in conjunction with this alternative to minimize the volume of waste brine, to provide additional disposal capacity and equalize the waste brine upstream of the injection well

Next steps for Near Term Alternative

If and when additional investigation of deep well injection is desirable, the following items need to be addressed:

- **Determine suitability of potential well sites in the project area**

  The depth, geology and hydrogeology of any potential well location need to be investigated and evaluated with respect to the ability to accept and disperse injected brine at a specified rate and over an estimated project life. This type of investigation and evaluation is typically performed as part of a feasibility study performed by a specialized consultant. A typical feasibility study for a project of this nature costs approximately $20,000 to $40,000.

- **Predesign and Permitting**

  If the results of a feasibility study are favorable to the project partners, the next steps would be preliminary design of a new or refurbished well and a transmission pipeline from the groundwater demineralization site. Identification of and application for necessary permits could be completed in parallel with predesign efforts. Based on recent EPA-issued permits, as described previously, it is anticipated that permitting for this disposal option is achievable and would be more dependent on technical development than obtaining a permit.

Long-Term Alternative: Brine Export via Pipeline

This option for brine management is considered to be a "very long-term" option as it will require significant permitting, partnering and engineering efforts prior to implementation. The major constraint for this option is coordination with the implementation of the PVWMA CVP Import Pipeline. The implementation of this alternative is largely out of the control of the Project Partners and requires coordination and negotiation with multiple regional agencies. A brine export pipeline would either connect with the planned CVP pipeline and would be used during the winter months or would parallel the entire pipeline to provide year-round disposal capacity.

Next Steps for Long Term Alternative

At this stage in the development of the PVWMA CVP Import Pipeline, there are few steps that can be taken with respect to development of this brine management alternative. The main actions are to continue to follow the potential implementation path of this project and be prepared to work with PVWMA and other project stakeholders to determine a method to implement this brine management alternative if the institutional arrangements can be developed to turn this concept into a reality.

Revenue Alternative: Product Recovery

Depending on the outcome of additional investigations and potential feasibility studies, product recovery may provide added benefits and reduced costs for the overall demineralization project. A product recovery process capable of producing high-value salt products, such as gypsum or magnesium hydroxide, could offset a portion of capital, operational, and maintenance costs for the project through the marketing and sale of these products. Other potential benefits include:

- Increased water recovery
- Decreased waste stream volume and mass loading

Next steps for Revenue Alternative

Following additional preliminary investigation of product recovery, the following items should be addressed prior to potential implementation:

- **Desktop Feasibility Study**

  A more detailed desktop feasibility study needs to be performed to determine the quantity and quality of recoverable salts that may be available, and the potential additional treatment processes required to enable their precipitation. Appendix L provides additional information based on work performed by LLNL and their FIC process. An analysis of potential markets for the sale of the recovered compounds would be necessary to fully understand the potential revenue from this process. GeoProcessors has experience in the marketing of reclaimed compounds and could assist in the execution of this analysis.

- **Pilot Testing**

  If the results of a feasibility study indicate potential for favorable implementation, a scaled pilot study may be conducted to validate the conclusions from the feasibility study and identify major design, operation and maintenance issues.

- **Predesign and Permitting**

  Following pilot study activities, the next steps would include the design of a product recovery treatment train. Identification of and application for necessary permits could be completed in parallel with design efforts.

It should be noted that neither the pursuit of the preferred near-term brine management approach nor the near- or long-term alternatives precludes the practicality of pursuing the revenue alternative. That is, product recovery, if deemed technically and economically feasible, could be inserted into a process train involving any of the other identified alternatives. The combination of the VSEP and product recovery processes would require specific study to evaluate the interactions.

4.7 Conclusions and Next Steps

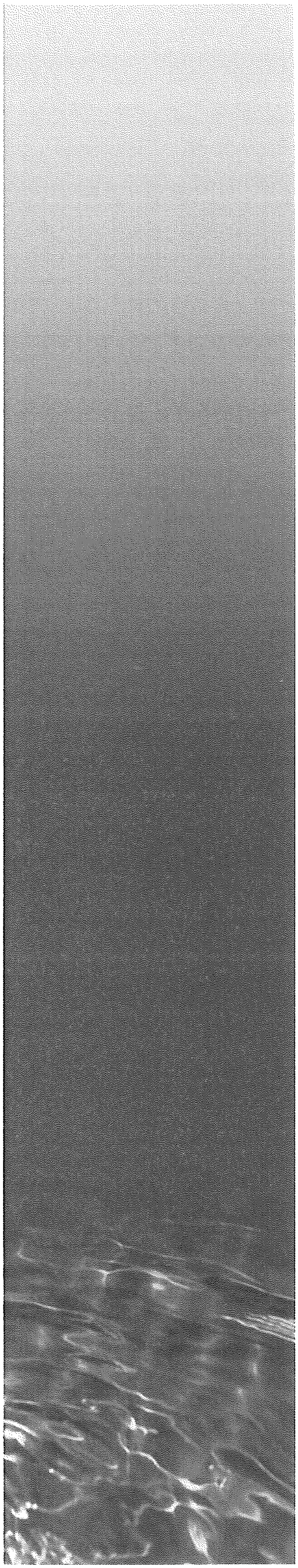
The current recommendation for brine management from a groundwater demineralization facility using the San Juan Valley as a water source is advanced concentration using a VSEP system followed by evaporation ponds and eventual landfilling of the dried solids. This overall management strategy would provide significant salt management benefits to the groundwater basins in the Upper Pajaro River Watershed while having a high potential for near-term implementation. Additional final disposal options are still under consideration because they appear to provide an opportunity for a more cost-effective approach to brine management. The final disposal options identified for additional study are:

- Deep well injection
- Export to Watsonville WWTP ocean outfall

Product recovery systems are also identified for additional study and could potentially replace the VSEP system as an advanced concentration unit while providing an additional revenue stream from the recovered compounds.

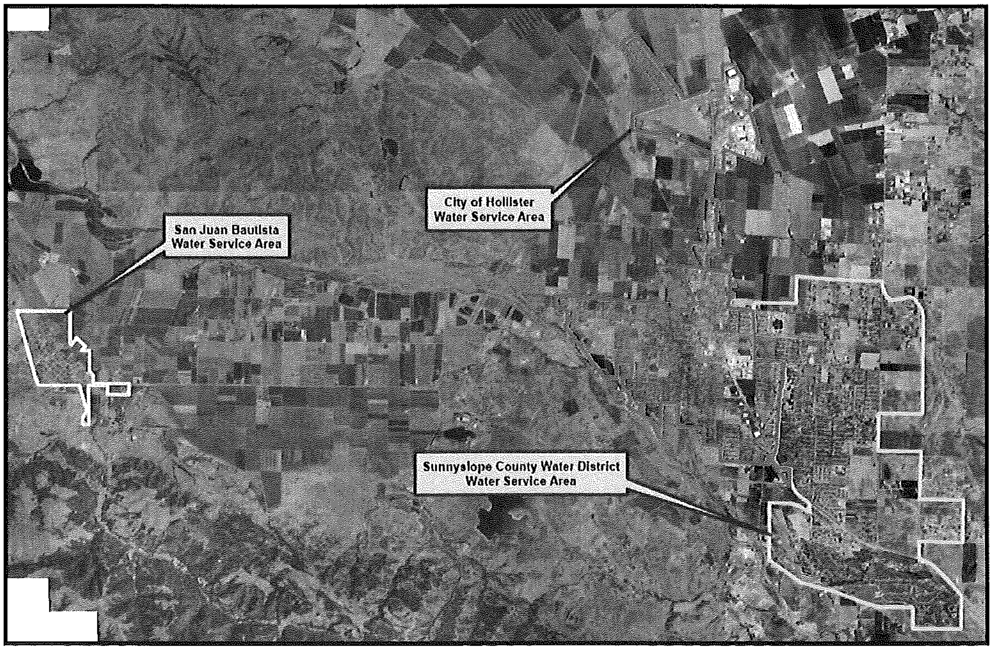
The recommended next steps for brine management are:

- Perform VSEP laboratory-scale testing on groundwater from the San Juan Valley
- Perform Feasibility Study for deep well injection in the area
- Refine recommendations, if needed, based on the results of these studies
- Refine and update cost estimates and implementation plans for the recommended brine management strategy



Chapter Five

Receiving Water Distribution System Evaluation



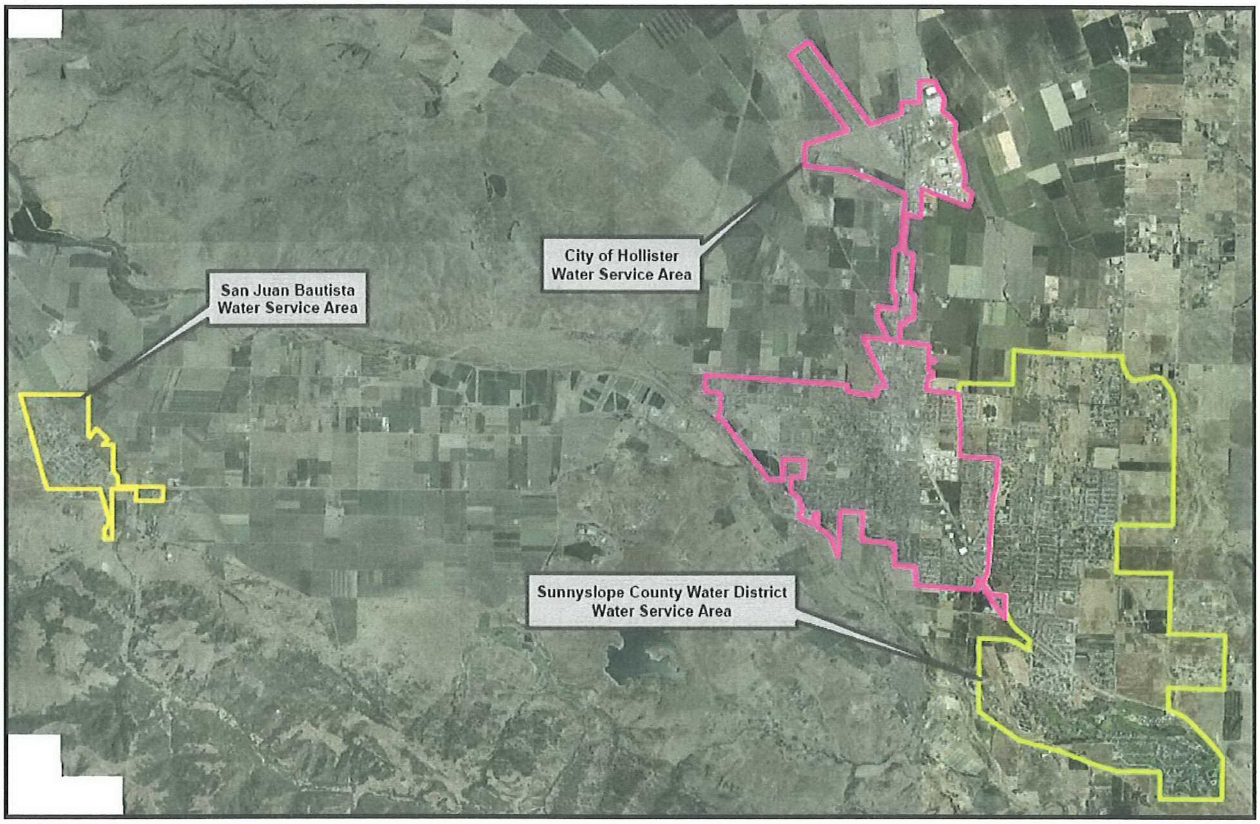
Pajaro River Watershed Groundwater Desalination Feasibility Study

Chapter 5 Receiving Water Distribution System Evaluation

5.1 Potential M&I System Locations

Northern San Benito County has three major potable water distribution systems: the City of Hollister system, the City of San Juan Bautista (SJB) system and the Sunnyslope County Water District (SSCWD) system. Figure 5-1 shows the approximate service area boundaries for these three major M&I water service providers in Northern San Benito County. Currently, these systems are supplied by groundwater and, for the City of Hollister and SSCWD, Central Valley Project (CVP) water. The Hollister and SSCWD systems are connected via interties to provide additional reliability and sharing of CVP water from the jointly-owned Lessalt Water Treatment Plant. Due to these interties and the location of the SSCWD system in relation to the San Juan Valley, the SSCWD system will not be considered apart from the City of Hollister system as a recipient of demineralized water from the San Juan Valley. The San Juan Bautista and Hollister systems will be evaluated for their potential to receive water from a groundwater demineralization facility supplied with water from the San Juan Valley.

Figure 5-1: Regional M&I Water Supply Service Areas


City of Hollister Water Service Area
San Juan Bautista Water Service Area
Sunnyslope County Water District Water Service Area

5.1.1 City of Hollister Urban Area

The City of Hollister is located just to the east of the San Juan Valley and is the major urban center of northern San Benito County. The City of Hollister Urban Area (including SSCWD service area) currently has a water demand of 7,965 AFY which is projected to increase to nearly 12,000 AFY by 2023 and to more than 20,000 AFY at full build-out conditions (HDR 2006). The City of Hollister is currently served by the interconnected City and SSCWD systems. The facilities currently in use to serve this area are summarized in Table 5-1.

Table 5-1: Existing Hollister Urban Area Water Supply Facilities

Facility Type	City of Hollister	SSCWD
Active Groundwater Wells	7 wells 6,465 gpm maximum pumping	4 wells 3,150 gpm maximum pumping
Storage Tanks/Reservoirs	4 (incl. 1 shared with SSCWD) 8.2 million gallons capacity	3 (incl. 1 shared with City) 2.5 million gallons capacity
Pressure Regulating Stations	2	7
Booster Stations	1	1
Distribution Piping	62 miles 4-inch to 16-inch	66 miles Various sizes
Surface Water Treatment Plant	3.0 MGD capacity to serve both City and SSCWD areas	

The water supply sources for this area are sampled and analyzed at various times throughout the year to ensure the water meets all Federal and State requirements. The results from these sampling activities are summarized in Table 5-2 and are compared to the State of California secondary drinking water standards and regional targets identified in the Memorandum of Understanding (MOU) that identifies the goals and relationships that govern the Hollister Urban Area Water and Wastewater Master Plan (HUAWWMP).

Table 5-2: Selected Hollister Area Water Quality Data

Constituent	2005 Average Concentration (City Wells)	2005 Average Concentration (SSCWD Wells)	Drinking Water Standard	MOU Target
Total Dissolved Solids	693 mg/L	808 mg/L	1,000 mg/L	500 mg/L
Chloride	99 mg/L	103 mg/L	500 mg/L	-
Sodium	105 mg/L	104 mg/L	-	-
Hardness	311 mg/L	393 mg/L	-	120 mg/L
Calcium	49 mg/L	70 mg/L	-	-
Magnesium	45 mg/L	53 mg/L	-	-
Alkalinity	247 mg/L as $CaCO_3$	295 mg/L as $CaCO_3$	-	-
pH	7.6	7.8	-	-

One 8-inch diameter distribution pipe extends along San Juan-Hollister Road towards the San Juan Valley from the City of Hollister. This pipe, however, is not large enough to convey the quantity of water planned to be supplied from the San Juan Valley therefore alternative connection options are required.

5.1.2 City of San Juan Bautista

The City of San Juan Bautista is located in the western half of the San Juan Valley and is a significantly smaller urban area than the Hollister Urban Area with a population of approximately 1,600. Current water demands for the City are approximately 440 AFY with potential increases to approximately 900 AFY anticipated in the future (Mark Davis, pers comm 1/2007). Current peak day demands are approximately 0.8 MGD with projected increases to 2.0 MGD at buildout conditions. The City currently owns three groundwater wells; however, only one well is currently used for continuous potable water supply. The other two wells are not used since one well has high concentrations of silt and is currently rented for agricultural irrigation while the other has high nitrate concentrations and can only be used in emergency situations. The City of San Juan Bautista water is currently supplied through the facilities summarized in Table 5-3. Implementation of a 0.75 MGD surface water ultrafiltration plant is on-going with a projected construction start of summer 2007. The facility is planned to be located near the intersection of San Juan-Hollister Road and Mission Vineyard Road, which is adjacent to an existing groundwater well. The connection of this surface water into the distribution system is planned to be in the immediate area of the treatment facility.

Table 5-3: City of San Juan Bautista Water Supply Facilities

Facility Type	City of San Juan Bautista
Active Groundwater Wells	3 wells (only 2 used for potable supply) 750 gpm maximum pumping (2 wells only)
Storage Tanks/Reservoirs	1 0.36 million gallons capacity
Pressure Regulating Stations	0
Booster Stations	0
Distribution Piping	2-inch to 12-inch asbestos-cement and cast iron/galvanized pipe
Surface Water Treatment Plant	Proposed 0.75 MGD ultrafiltration facility to serve City water demands with blending of local groundwater

The water supply sources for this area are sampled and analyzed at various times to ensure the water meets all Federal and State requirements. The results from these sampling activities are summarized in Table 5-4 and are compared to the State of California secondary drinking water standards and regional targets identified in the HUAWWMP MOU. The City of San Juan Bautista is not a party to this MOU, however the target values are included for comparative purposes.

Table 5-4: Selected San Juan Bautista Water Quality Data

Constituent	2005 Average Concentration	Drinking Water Standard	MOU Target
Total Dissolved Solids	662 mg/L	1,000 mg/L	500 mg/L
Chloride	88 mg/L	500 mg/L	-
Sodium	58 mg/L	-	-
Hardness	489 mg/L	-	120 mg/L
Calcium	143 mg/L	-	-
Magnesium	58 mg/L	-	-
Alkalinity	340 mg/L as $CaCO_3$	-	-
pH	7.1	-	-

A groundwater demineralization facility in the San Juan Valley could convey treated water to the location of the proposed City of San Juan Bautista surface water treatment facility. From this point, the same alignment proposed to connect to the proposed San Juan Bautista surface water treatment facility to the existing City potable water system could be utilized to serve City customers.

5.2 Water Quality and Hydraulic Limitations to Use

Introduction of the product water from a demineralization system may require mitigation of certain factors prior to successful and optimum use in an existing potable water distribution system. The major factors include:

- Water quality considerations
- Existing distribution system capacity
- Storage requirements

5.2.1 Water Quality Considerations

A demineralization facility treating groundwater from the San Juan Valley would be configured to produce a blended (reverse osmosis product water with raw groundwater) supply with a TDS concentration of 300 mg/L. The HUAWWMP is developing the implementation strategy for demineralization of groundwater to serve the Hollister Urban Area which is projected to include demineralization of existing urban wells, continued treatment of imported Central Valley Project (CVP) surface water and demineralization of groundwater from the San Juan Basin. Based on the proposed quality of each of these water sources, the 300 mg/L TDS target from this demineralization project will allow the City of Hollister, the San Benito County Water District and San Benito County to achieve the recycled water salinity goals set in the HUAWWMP MOU. Implementation of the full suite of proposed projects will ensure that similar water qualities are distributed to customers throughout the Hollister Urban Area.

In addition to the TDS concentration, reverse osmosis processes can have an impact on the corrosion potential and the "aggressiveness" of the water. The main reason for these changes is the conversion of alkalinity in the feed water to dissolved carbon dioxide in the product water. To mitigate this change, two methods may provide the required reductions:

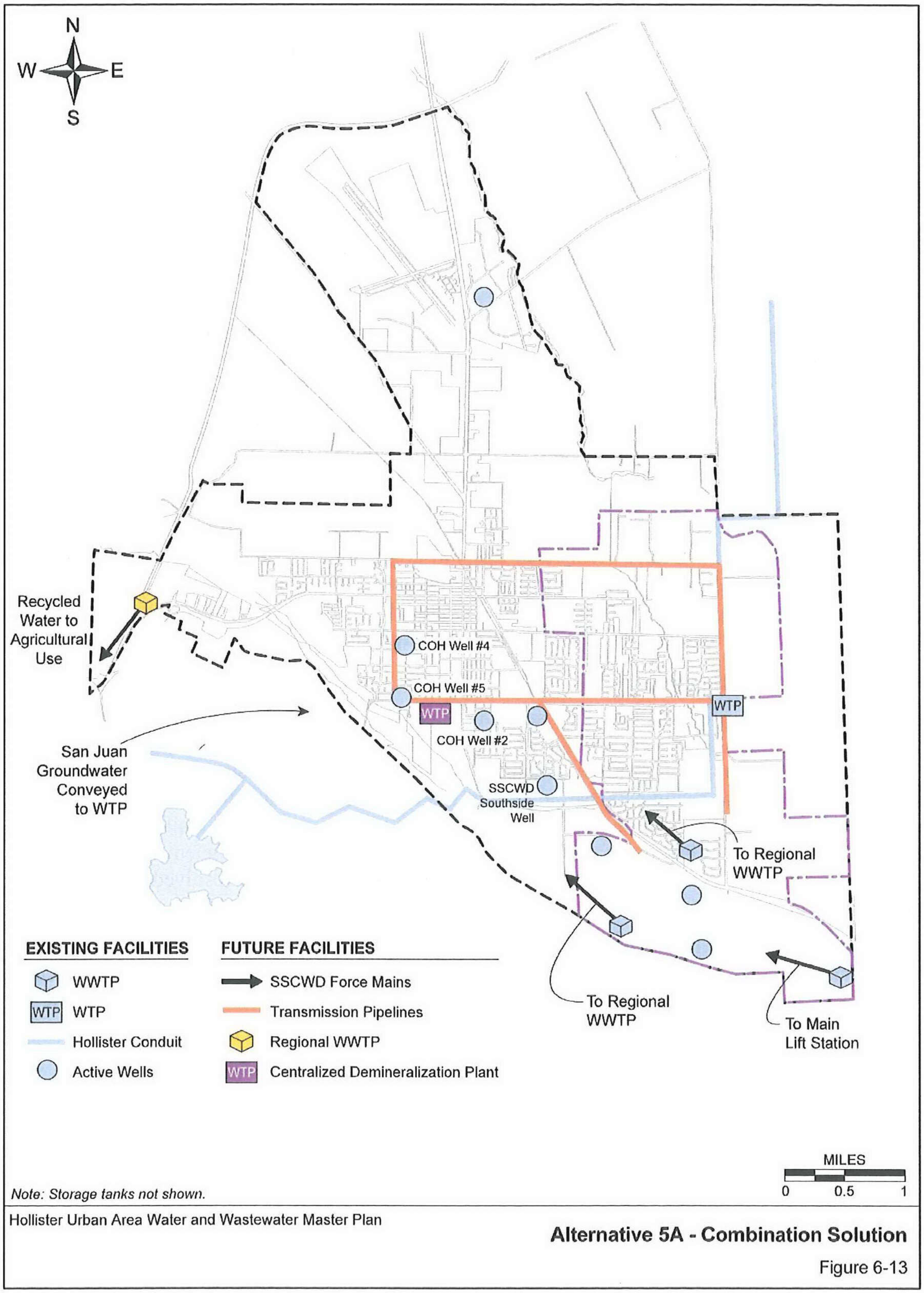
- Blending with raw groundwater – If the ratio of raw water to product water is appropriate, the lower concentrations of dissolved carbon dioxide in the raw water can reduce the overall concentration in the blended water. To meet the 300 mg/L TDS water quality, approximately 88% of the total blended water flow is required to be RO product water.
- Decarbonation – This treatment process involves distributing the RO product water through a decarbonation tower to allow the dissolved carbon dioxide to be diffused into the air passing through the water. The product water after this process will contain substantially less carbon dioxide and will be less corrosive to piping and fixtures in the distribution system.

To ensure the required reduction in carbon dioxide concentration in the product water, it is assumed that decarbonation towers will be required to reduce the corrosion potential of the water. Specific pilot testing will be required to ascertain the actual need for decarbonation in the demineralization facility based on the actual source water and the membrane selected.

5.2.2 Existing Distribution System Capacity

The existing City of Hollister potable water system is not configured to receive a large flow rate of water at a single point. Currently, water is supplied to the system from groundwater wells distributed throughout the City. To add a new source of water from the San Juan Valley, the construction of large-diameter transmission pipelines within the City would be required to evenly distribute the water to all customers without overwhelming the existing supply infrastructure. Each alternative proposed by the HUAWWMP includes the installation of a looped system of 24-inch diameter transmission pipelines. The recommended water supply improvements, including this transmission pipeline loop, are shown in Figure 5-2.

Figure 5-2: HUAWWMP Recommended Water Supply Facilities



This transmission pipeline loop would allow high quality water from multiple sources to be evenly distributed throughout the City regardless of the location of the specific water source. The sources that are tentatively identified for inclusion into this loop system are the demineralized groundwater from the San Juan Valley, demineralized groundwater from existing City of Hollister municipal supply wells and treated surface water from the Lessalt water treatment plant. The maximum benefit of the San Juan Valley demineralization facility would be derived through a connection to this system which would allow the water to benefit all customers in the City of Hollister.

The City of San Juan Bautista currently has plans to augment its existing groundwater supply with a surface water supply with a single point connection. There are two main alternatives for incorporation of a demineralized groundwater supply into this system:

- Replace the water produced by the surface water filtration facility with demineralized groundwater, or
- Augment surface water with demineralized groundwater to provide a high quality, reliable water supply for the City.

San Juan Bautista is planning implementation of the surface water treatment facility. However, the use of demineralized groundwater could provide a cost-effective alternative to treated surface water. Alternatively, since the surface water filtration plant is anticipated to be constructed in the very near future, the demineralized groundwater could be used to augment this facility if future demand exceeds the City's surface water supply. Due to these unknowns, the demineralized supply is assumed to be connected to the City distribution system near the connection point for the surface water treatment facility. Growth projections have resulted in plans to upgrade the existing water distribution system to better accommodate existing customers and projected growth. Implementation of the distribution system improvements has not yet been scheduled. It is assumed that distribution pipelines near the proposed surface water treatment facility would be upsized to accommodate future growth requirements.

5.2.3 Storage Requirements

Both the City of Hollister and City of San Juan Bautista water supply systems have existing storage facilities, mainly elevated tanks, to provide additional reliability and peak period water supplies. The City of San Juan Bautista has identified required increases in its system storage and is pursuing implementation of these facilities separately from the demineralization efforts. The HUAWWMP has identified a projected storage deficit of approximately 20 million gallons for buildout conditions in the Hollister urban area. Mitigation of this deficit is required to maintain sufficient capacity in the water supply and distribution system. These storage needs are anticipated to be resolved separately from any demineralization project implementation.

The demineralization facility would include operational storage to allow reduced production during routine maintenance of the demineralization facility. Current plans identify 8-hours of storage capacity at the demineralization facility. For 2.68 MGD of product water capacity, this would result in a 0.9 million gallons of storage. This storage would also assist in providing water during periods of peak water demands.

5.3 Potential Pipeline Alignments

The recommended wellfield location along Highway 156 between Lucy Brown Lane and Bixby Road is a centralized location in the San Juan Valley and has been shown, via groundwater modeling, to provide water level benefits throughout the San Juan Valley while minimizing any negative impacts to the region. Due to the large demands anticipated in the City of Hollister through 2023, it is anticipated that the demineralization facility would be at least partially utilized to meet these additional demands. For the purposes of this evaluation, it is assumed that the treatment facility is located in close proximity to the wellfield.

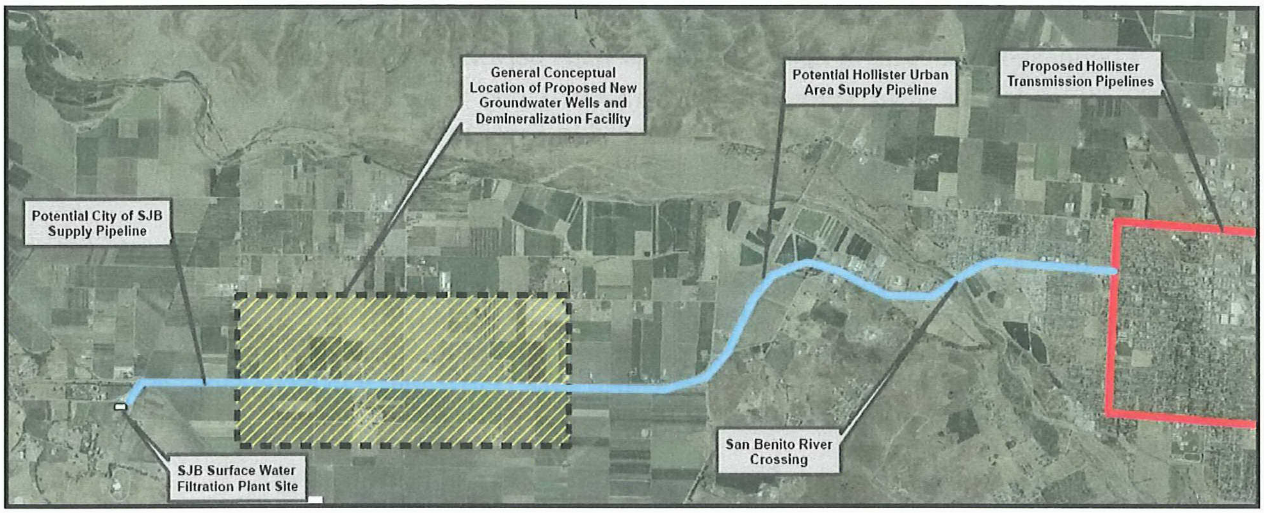
5.3.1 Distribution Alternatives

Depending on the priority given to providing demineralized groundwater to the City of San Juan Bautista, there are two general alternatives:

- Supply the product water to the Hollister Urban Area and San Juan Bautista
- Supply the product water only to Hollister

Figure 5-3 summarizes the conceptual distribution infrastructure that would be associated with the demineralization facility. The locations shown for the individual elements are conceptual only and are not intended to represent final locations of the infrastructure.

Figure 5-3: Conceptual Product Water Connection Infrastructure


General Conceptual Location of Proposed New Groundwater Wells and Demineralization Facility
Potential Hollister Urban Area Supply Pipeline
Proposed Hollister Transmission Pipelines
Potential City of SJB Supply Pipeline
San Benito River Crossing
SJB Surface Water Filtration Plant Site

5.3.2 City of Hollister Connection

Demineralized groundwater from the San Juan Valley has been identified as an integral aspect of water supply planning for the Hollister Urban Area and has been recommended for implementation in the HUAWWMP. Assuming that the transmission pipeline system identified in the HUAWWMP is implemented, one potential connection point from the San Juan Valley would be at the northwest corner of the transmission pipeline system. This location is near the intersection of Buena Vista Road and Line Street.

This connection point would require approximately 4.5 miles of pipeline from the identified wellfield location. To convey peak flows, estimated at 200% of the average flows, an 18-inch pipeline would be required to maintain the head loss through the pipeline at an acceptable level. For average flow conditions, 1,860 gpm, the velocity in this pipeline is approximately 2.3 feet per second while at peak flow conditions, 3,720 gpm, the pipeline velocity is 4.7 feet per second. Under average conditions two 930 gpm, 100 HP pumps would be required to convey the water to the connection point with a discharge pressure of 80 psi. Peak conditions would require use of five 930 gpm, 100 HP pumps to convey the flows to the connection point at the same pressure. Major construction constraints for the product water conveyance pipeline include:

- Obtaining CalTrans approval for pipeline installation along Highway 156
- Crossing of the San Benito River
- Considerations for existing buried utility infrastructure protection and avoidance in urban and residential streets

5.3.3 City of San Juan Bautista Connection

To provide potable water service to the City of San Juan Bautista, the demineralized groundwater could be connected into the existing potable water system in the same manner as the surface water treatment facility. A connection point for the treated groundwater has been identified near the surface water treatment facility, approximately 1.5 miles from the wellfield. Assuming that the demineralization facility is in close proximity to the wellfield, 2 miles of pipeline would be required for a City of San Juan Bautista connection. For the identified future peak flow of approximately 1,390 gpm (2.0 MGD), and a treated surface water supply of 520 gpm (0.75 MGD), a 10-inch pipe would be required to supply the remaining 870 gpm (1.25 MGD). Major construction constraints for the treated groundwater pipeline include:

- Obtaining CalTrans approval for pipeline installation along Highway 156
- Coordination with City of San Juan Bautista water department for connection requirements

Alternatively, if the San Juan Valley demineralization facility is located near the City of Hollister, a smaller demineralization facility could be constructed to serve San Juan Bautista and raw groundwater could be conveyed to that treatment site. This, however, would complicate waste concentrate management as there would be two sites generating the waste product.

Coordination with the on-going plans for the City of San Juan Bautista and how best to integrate the proposed demineralization facility into their system operation will be required as the implementation of their surface water treatment facility progresses. Given the uncertainty of the delivery of product water to the City of San Juan Bautista, the remainder of this analysis will focus on the required infrastructure to supply the product water to the City of Hollister Urban Area. Provisions will be provided in the pumping and piping systems to allow for a connection to SJB at some point in the future.

5.4 Operational Strategy for Extraction and Treatment

To properly plan for facility operation, an assessment of the receiving system demands is needed. Both variations over the course of a year and variations over the course of a day will influence the operational strategy for the groundwater wells and the demineralization facility. Coordination between raw groundwater storage, treatment process capacity and product water storage will be required to minimize the flow rate changes through the demineralization process and to provide the required quantity of high quality water to the distribution systems. This specific coordination between the sizing and operation of the different elements will need to be performed during the detailed planning and design stages of this project.

5.5 Distribution Project Recommendations

Based on the previous analysis, it is recommended that up to 3,000 AFY of product water be supplied to the Hollister Urban Area to meet its 2015 water supply needs while monitoring water supply needs for the City of San Juan Bautista to determine whether or not a connection to the City is a viable option for the region. Table 5-5 summarizes the required sizing of the components of the product water distribution aspects of the demineralization facility.

Table 5-5: Proposed Water Distribution System Summary

Process	Size or Capacity
Product Water Storage	900,000 gallons
Delivery Pressure	80 psi
Product Water Pumps [a]	5 pumps at 930 gpm, 100 HP each
Facility Location [b]	Within ½ mile of wellfield
Product Water Pipe Diameter	18-inches
Product Water Pipe Length	4.5 miles

Notes:
a – This pumping capacity would allow for distribution of water in peak situations up to twice the average production rate.
b – Final facility location is still under consideration and the location stated is for cost evaluation purposes only.

The cost estimates for the facility described above are based on the criteria and limitations summarized in Table 5-6. The capital costs for this aspect of the demineralization project are escalated to June 2014, the projected mid-point of construction, from the base cost reference of May 2007. The escalation is performed using an inflation rate based on the average annual change in the Engineering News Record San Francisco Construction Cost Index (ENR SF CCI) values between January 1996 (6546.74) and December 2006 (9108.66).

Table 5-7 summarizes the capital costs and Table 5-8 summarizes the estimated annual operations and maintenance (O&M) costs for the demineralization treatment aspects of the overall project.

Table 5-6: Cost Estimate Development Criteria

Element	Value/Unit Cost
Storage Cost	$1.70/gallon
Pump Station	$2,700/installed HP
Distribution Piping (18-inch)	$145/SF
Corrosion Protection	$16,000/mile
Consumables (equipment, mechanical, electrical, instrumentation)	2% of capital cost
Electricity Costs	$0.15/kWh
Operator Labor	$60/hour
Regulatory Testing Costs	$25,000/year
Cost Estimate Reference	May 2007
Cost Estimate Index (ENR SF CCI)	9116.72
Annual Inflation Rate (average annual EDR SF CCI increase over past 10 years)	3.9%

Table 5-7: Distribution Capital Cost Estimate

Component	Cost Estimate
Product Water Storage	$1,535,000
Product Water Pumping	$1,855,000
Chlorination Facilities	$108,000
Product Water Piping	$3,863,000
Raw Construction Cost	**$7,360,000**
Project Contingency (30%)	$2,210,000
Change Order Contingency (5%)	$480,000
Engineering/Environmental Allowance (20%)	$1,910,000
Legal/Administrative Allowance (10%)	$960,000
Construction Management Allowance (10%)	$960,000
Total Capital Cost (2007)	**$13,880,000**
Annualized Capital Cost (30 year, 5%, 2007)	**$903,000**
Total Capital Cost (2014)	**$18,140,000**
Annualized Capital Cost (30 year, 5%, 2014)	**$1,180,000**

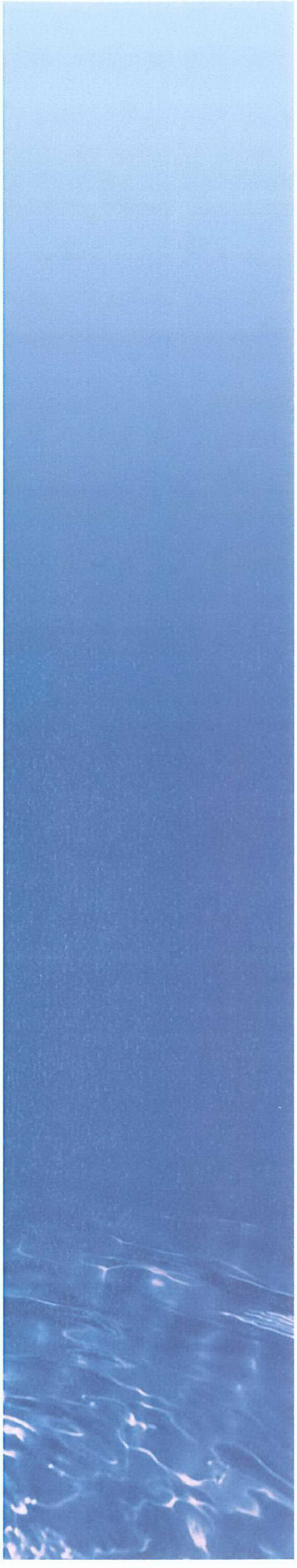
Table 5-8: Distribution O&M Cost Estimate

Component	Cost Estimate
Consumables (incl. testing)	$170,000
Energy	$100,000
Labor	$25,000
Chemicals	$25,000
Total Annual O&M Cost (2007)	**$320,000**
Present Worth O&M Cost (30 year, 5%, 2007)	**$54920,000**
Total Annual O&M Cost (2014)	**$420,000**
Present Worth O&M Cost (30 year, 5%, 2014)	**$6,460,000**

5.6 Next Steps

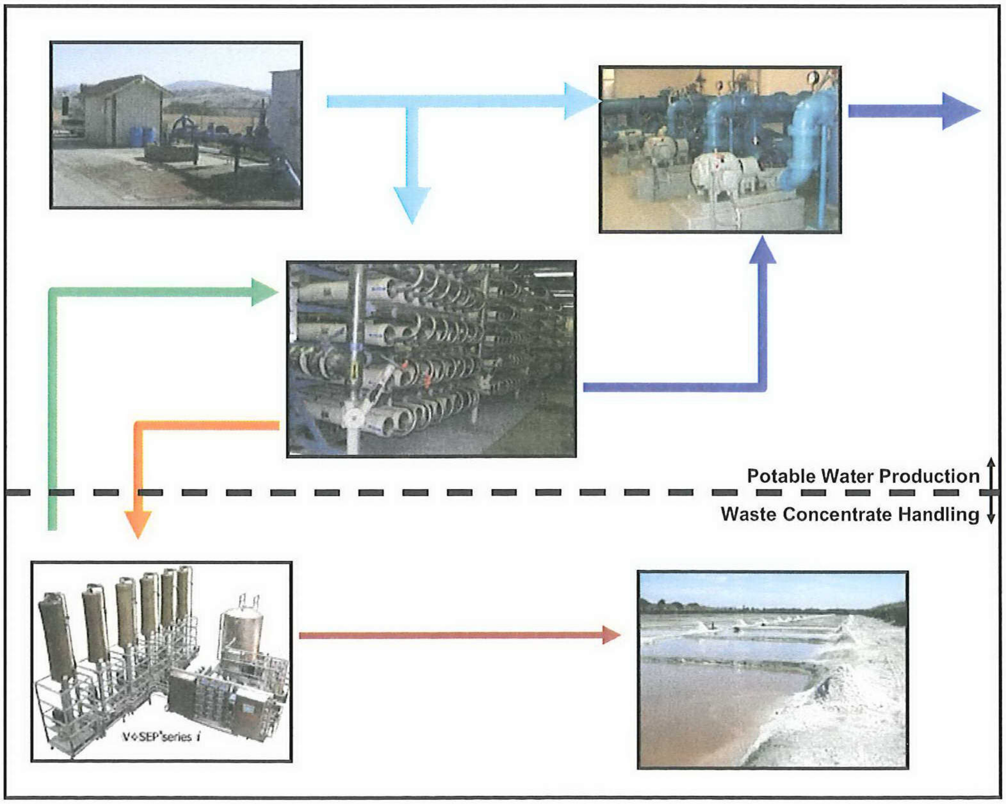
One follow-on step for this project is to develop a preliminary engineering report that would take information developed from other aspects of this Feasibility Study to identify a complete groundwater extraction/demineralization/distribution/concentrate disposal project for the Pajaro River Watershed. With respect to distribution, key information to be developed at that stage includes the determination of:

- Anticipated demand and schedule for demineralized supply at San Juan Bautista
- Temporal variations in demand for the Hollister Urban Area and the City of San Juan Bautista
- Physical sizing and configuration of product water storage and pumping facilities
- Specific distribution pipeline alignment alternatives
- Specific connection points into the City of Hollister transmission piping loop



Chapter Six

Recommended Plan and Benefit Assessment



Pajaro River Watershed Groundwater Desalination Feasibility Study

Chapter 6 Recommended Plan and Benefit Assessment

6.1 Recommended Project

One of the primary purposes of the Pajaro River Watershed Groundwater Desalination Feasibility Study is to identify ways in which to address regional water supply issues and to improve existing water supply reliability. The San Benito County Water District and the Santa Clara Valley Water District receive water supplies through the Central Valley Project (CVP) San Felipe Division. The ability to effectively manage available water supplies is an overriding objective of both water districts. To that end, the two districts' recent CVP contract renewal negotiations have resulted in identification of a "joint service area" which would facilitate CVP water transfers between the San Benito County and Santa Clara Valley Water Districts. Any such transfers could be made based solely on an agreement between the two districts without additional Bureau of Reclamation approval. This ability to transfer water between the two districts creates greater opportunity for mutually beneficial projects and water resource management strategies. It is anticipated the Pajaro Valley Water Management Agency would have similar flexibility once it begins taking delivery of CVP water supplies.

Based on previous Technical Memoranda, a groundwater desalination project is feasible as a basis to develop a new potable water supply within the Pajaro River Watershed. Conceptually the facility would treat water from the San Juan Basin and deliver potable water to the greater Hollister urban area, and potentially the San Juan Bautista area. Development of the groundwater desalination project would provide potential benefits beyond the specific area receiving the desalinated groundwater. The following sections describe how a desalination facility can develop a new potable water supply that enables the opportunity for water transfers between the regional water agencies consistent with the objectives described above. The major project infrastructure components include:

- Groundwater extraction and conveyance
- Desalination treatment
- Concentrate management
- Product water storage and distribution

The recommended alternatives for each of these elements are summarized in the following sections.

6.1.1 Groundwater Extraction and Conveyance

Based on groundwater basin modeling performed as part of this study and as part of the Hollister Urban Area Water and Wastewater Master Plan (HUAWWMP) the San Juan Basin can support sustained extractions of up to approximately 4,300 acre-feet per year (AFY) with the implementation of certain mitigation measures. To ensure that overdraft conditions are not reintroduced, after having been successfully mitigated during the mid-1980s, the HUAWWMP plan identifies a potable supply of 3,000 AFY from the San Juan Basin. The total pumping from the basin would equal the total of the desired supply (3,000 AFY) plus the quantity of waste concentrate produced from the desalination process, which is dependent on the water recovery of the overall treatment process. Estimated water recoveries range between approximately 80% and 98%, depending on the efficiencies of specific elements of the treatment system, resulting in concentrate volumes of 750 AFY and 65 AFY, respectively. Therefore, total pumping from the San Juan Basin could range between 3,065 AFY and 3,750 AFY, both within the allowable extractions of 4,300 AFY. Because the cost of concentrate disposal drives the total project cost, the final concentrate management alternative will drive the required water recovery, and by extension the actual pumping rate.

Following development of a recommended waste concentrate management strategy, a total system water recovery of 98% was identified as the project recommendation based on a reverse osmosis water recovery of 83% and the remaining 15% of the recovery achieved through the use of advanced brine concentration and associated water recovery. The total pumping is projected to be spread over a series of six wells screened from 150 feet to 500 feet below the surface with maximum pumping rates of 500 gpm each. This design assumes that each well is only active for 16 hours per day, allowing for maintenance downtime and aquifer recovery. The wells are proposed to be located in a line parallel to Highway 156 between Lucy Brown Lane and Bixby Road. Conveyance of the raw groundwater, at a maximum rate of 3,000 gallons per minute (gpm), would require pipelines ranging from 8 to 16-inches in diameter between the wells and an 18-inch diameter pipeline from the wellfield to the groundwater desalination facility. The location of the desalination facility is discussed in the following section.

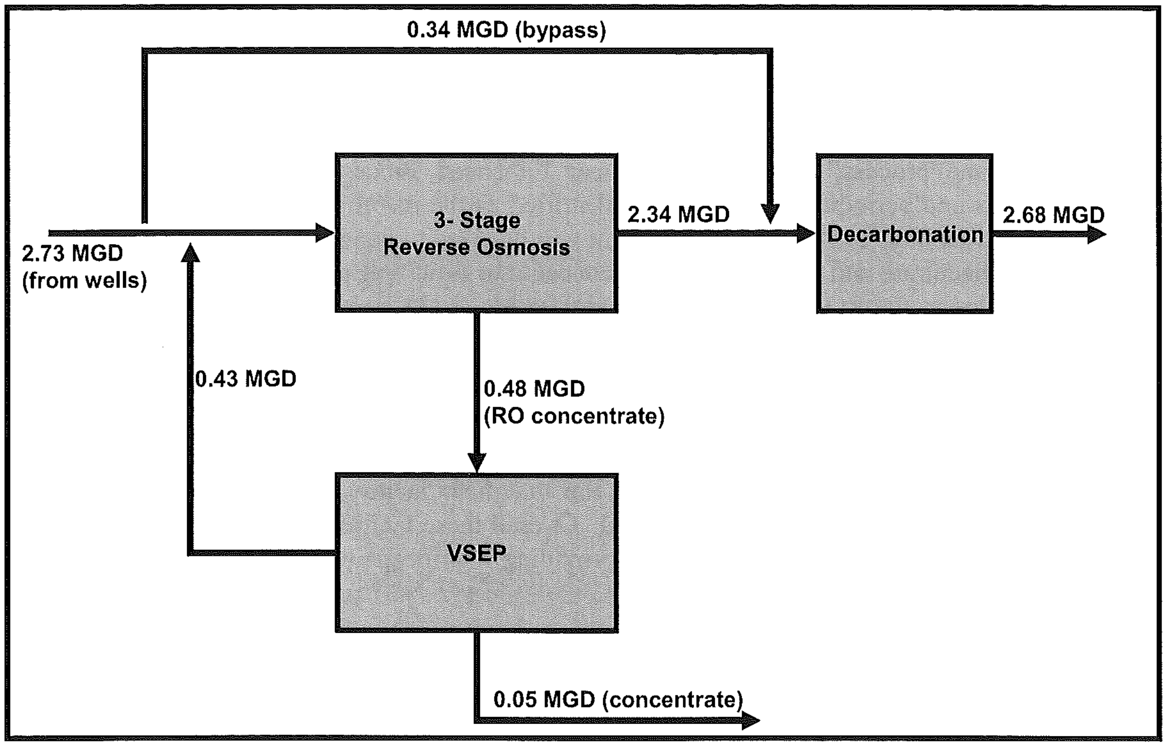
That previous analysis does not incorporate the associated impacts of the City of San Juan Bautista receiving desalinated groundwater. From an overall basin perspective, such a supply would be a direct offset from the existing pumping operations for the City. The additional pumping required to account for the generation of the waste concentrate would result in an additional 10 to 110 AFY of groundwater. For the high recovery scenario, the additional 10 AFY would likely not have a perceptible impact on the overall groundwater basin conditions, however the lower recovery scenario may result in decreased groundwater levels. For the purposes of this Study, it is assumed that the City of San Juan Bautista would not be supplied with desalinated groundwater and would rely on their planned CVP water treatment facility for existing and future water supplies.

6.1.2 Desalination Treatment

The desalination facility would remove dissolved constituents from a portion of the pumped raw groundwater and would blend this treated groundwater with a small fraction of raw groundwater to produce potable water with an approximate total dissolved solids (TDS) concentration of 300 mg/L. This TDS concentration has been determined through the HUAWWMP to result in treated recycled water with a TDS concentration between 500 mg/L and 700 mg/L. This goal is one of the main drivers for the recommended water supply elements in the HUAWWMP.

The treatment process is planned to include raw groundwater storage, cartridge filters, high pressure membrane feed pumps, low-energy reverse osmosis membranes and decarbonation. Product water storage, pumping and conveyance is discussed in a following section. Figure 6-1 summarizes the major components of the desalination system and the corresponding flow rates for the various flow streams.

Figure 6-1: Schematic Flow Diagram for Complete Desalination System



Based on the specific water quality parameters from the San Juan Basin, a three-stage reverse osmosis process by itself is anticipated to yield between 80% and 85% water recovery, with any additional water recovery accomplished through advanced concentration of the waste product from the RO process. For the purposes of this evaluation, a water recovery of 83% has been assumed. The treatment capacity is dependent on several parameters including:

- Volume of raw groundwater storage: provided to equalize the groundwater flow during periods of low well pumping
- Intended operation of the treatment facility: whether the product water will be used to satisfy base demand or will be used to supply peak demands
- Volume of product water storage

For the purposes of this evaluation, and until a more detailed assessment of the facility operation is completed, it is assumed that the raw groundwater will be fully equalized and a steady flow will be provided as influent to the desalination facility. The facility will also be assumed to be operated as a base demand facility and operate at a relatively constant rate over the course of a year due to the complications with start-up and shut-down of the membrane process. With these assumptions, the facility would require a product water capacity of 2.68 million gallons per day (MGD) to produce 3,000 AFY. Given the projected desalinated and raw groundwater TDS concentrations, 96 mg/L and 1,800 mg/L respectively, this would require 2.34 MGD of desalination capacity and 0.34 MGD of raw groundwater bypass piping. Variations in plant operational strategy may require additional membrane capacity to be installed to allow production of the full 3,000 AFY from the San Juan Valley.

The specific location of the treatment facility has not been identified at this stage of the planning process. To allow for maximum flexibility in the provision of water to the City of Hollister and the City of San Juan Bautista it is assumed that the treatment facility would be located in close proximity to the wellfield location. The treatment facility is assumed to require a land purchase of approximately 1-2 acres to include the membrane process, on site storage and the associated support processes. The final location of the treatment facility will be evaluated during the detailed design phase of project implementation, and will need to be closely coordinated with the recommendations contained in the HUAWWMP.

6.1.3 Concentrate Management

The proposed groundwater reverse osmosis facility is projected to produce 0.48 MGD (333 gpm) of waste concentrate for a total of approximately 540 AFY. Minimization of the volume of waste material using a vibrating membrane process, the Vibratory Shear Enhanced Process (VSEP), in conjunction with evaporation ponds and periodic salt removal is identified as the recommended concentrate management alternative for this facility[10]. The VSEP equipment will be sized to handle up to 0.50 MGD (350 gpm) of influent waste concentrate and for the projected concentrate flow will produce 0.43 MGD (300 gpm) of water to be recycled to the RO influent stream and 0.05 MGD (33 gpm) of a concentrate waste product. This waste product, with a projected TDS concentration of 85,370 mg/L, will be sent to a 20 acre evaporation pond site, where multiple ponds will be operated, for additional concentration. Salt will be removed from the groundwater basin through periodic excavation of the dried salts from the bottom of the lined ponds.

The VSEP units are projected to be located at the treatment facility while the final location for the evaporation pond site has not yet been determined. Overall these facilities are estimated to remove 6,200 tons of salt from the Pajaro River Watershed, providing significant benefits to the local groundwater basins and all associated users.

6.1.4 Product Water Storage and Distribution

The product water from the desalination facility, a blend of raw groundwater and desalinated groundwater with a TDS concentration of 300 mg/L, is planned to be delivered to urban areas in the vicinity of the San Juan Valley. Both the City of Hollister and the City of San Juan Bautista have potable water improvement needs and would be suitable candidates to receive this high quality potable water. The City of Hollister has a need for supply improvements by 2015 while the City of San Juan Bautista has an immediate need due to water quality and reliability concerns. The difference in the timing and the magnitude of these needs (3,000 AFY for Hollister and 500 AFY for San Juan Bautista) make a project that will assist the City of San Juan Bautista difficult to effectively implement and they are likely to pursue water supply improvements using other methods. For this reason, the desalinated groundwater is primarily slated to be delivered to the City of Hollister with incorporated provisions to provide sufficient capacity and piping connections to supply desalinated groundwater to the City of San Juan Bautista. Supply to the City of San Juan Bautista would require additional membrane capacity and an analysis of the impacts of the increased pumping on the aquifer. Additional groundwater wells may also be required to provide this additional water supply.

The desalination facility is planned to include a storage tank to provide operational flexibility and enhance reliability. The planned storage capacity for up to 8-hours of product water corresponds to a storage volume of approximately 0.9 million gallons. The storage tank is planned to be a circular, partially buried, covered facility with a connection back to the product water pump station to allow the water to be sent to the distribution system. Storage requirements in the City of Hollister and Sunnyslope County Water District water systems were addressed in the HUAWWMP and are not evaluated here. It is assumed that the City of San Juan Bautista either currently has sufficient storage or will develop separate plans for sufficient storage in the distribution system to meet the needs of its customers.

The connection to the Hollister Urban Area water distribution system is proposed tie into the transmission pipeline loop that is proposed by the HUAWWMP. This would allow the water to be distributed throughout the Area and provide benefits to a large number of water users. A connection to the City of

---

[10] Deep well injection and product recovery are potential alternatives to this recommendation and more information is required prior to a final decision on the waste concentrate management method.

San Juan Bautista water supply system is proposed to be located in the same place as the connection for their proposed surface water treatment facility. This would facilitate blending between the two sources if both are used to meet demands on the City water supply system. The connection from the treatment facility would require an 18-inch pipe to the Hollister Area and a 10-inch pipe to the City of San Juan Bautista.

6.1.5 Estimated Costs

Table 6-1, Table 6-2 and Table 6-3 summarize the estimated costs for the complete groundwater desalination project. The base costs are referenced to May 2007 (ENR SF CCI = 9116.72) and are presented after inflation to June 2014, the projected mid-point of construction. The total annual costs are used as the basis for the unit costs ($/AFY) for the desalinated groundwater.

Table 6-1: Overall Project Capital Cost Summary

Project Element	TOTAL CAPITAL COST (2007)	Annualized Capital Cost (2007)	TOTAL CAPITAL COST (2014)	Annualized Capital Cost (2014)
Groundwater Extraction & Conveyance	$6,000,000	$400,000	$7,900,000	$500,000
Desalination Treatment	$6,500,000	$400,000	$8,600,000	$600,000
Concentrate Management (VSEP plus ponds)	$25,100,000	$1,700,000	$32,800,000	$2,100,000
Product Water Storage and Distribution	$13,900,000	$900,000	$18,100,000	$1,200,000
TOTAL PROJECT	**$51,500,000**	**$3,400,000**	**$67,400,000**	**$4,400,000**

Table 6-2: Overall Project O&M Cost Summary

Project Element	TOTAL ANNUAL O&M COST (2007)	Present Worth O&M Cost (2007)	TOTAL ANNUAL O&M COST (2014)	Present Worth O&M Cost (2014)
Groundwater Extraction & Conveyance	$100,000	$1,600,000	$100,000	$2,100,000
Desalination Treatment	$400,000	$6,600,000	$600,000	$8,600,000
Concentrate Management (VSEP plus ponds)	$2,500,000	$37,600,000	$3,200,000	$49,100,000
Product Water Storage and Distribution	$300,000	$4,900,000	$400,000	$6,500,000
TOTAL PROJECT	**$3,300,000**	**$50,700,000**	**$4,300,000**	**$66,300,000**

Table 6-3: Overall Project Total Cost Summary

Project Element	TOTAL ANNUAL COST (2007)	TOTAL PRESENT WORTH COSTS (2007)	TOTAL ANNUAL COST (2014)	TOTAL PRESENT WORTH COSTS (2014)
Groundwater Extraction & Conveyance	$500,000	$7,700,000	$600,000	$10,000,000
Desalination Treatment	$900,000	$13,100,000	$1,200,000	$17,100,000
Concentrate Management	$4,100,000	$62,700,000	$5,300,000	$81,900,000
Product Water Storage and Distribution	$1,200,000	$18,800,000	$1,600,000	$24,600,000
TOTAL PROJECT	**$6,700,000**	**$102,300,000**	**$8,700,000**	**$133,600,000**

The proposed facility would produce 3,000 AFY of groundwater (desalinated groundwater blended with untreated groundwater) for potable water use resulting in a total unit cost of approximately $2,200/AF in 2007 dollars, and approximately $2,900/AF projected to 2014 costs.

6.1.6 Project Cost-Saving Concepts

The total unit cost (for 2014 project costs) for the desalinated groundwater is estimated to be approximately $2,900/AF, of which over 60% is incurred in management of the waste concentrate. Reductions in the overall cost for this aspect of the project would result in a significant reduction in the overall financial impact of the project. Three main options for cost savings in the waste concentrate management were identified:

- **Investigate Deep Well Injection for Concentrate Management/Disposal** – While deep well injection was determined to have a lower life cycle cost than the other identified alternatives, this option was not recommended as the primary brine management alternative due to the need to ascertain the specific feasibility of deep well injection in the Pajaro River Watershed Area. The first step in this process is to perform a deep well injection feasibility study. This study would provide information on the technical feasibility of operation of an injection well in the area.

  The critical step of such a study is a geologic review of the area. This would involve gathering well logs and map data from the California Department of Oil and Gas and other private sources and preparing a stratiographic view of the subsurface formations in the study area. Data would be used to determine:

  - Depth and injection capacity of potential injection zones
  - Depth and adequacy of confining formations
  - Depth of the base of the lowest underground source of drinking water
  - Potentially abnormally pressured zones that may be drilled through during the well installation process

  Following the geologic review, the feasibility study could conclude with a regulatory review analyzing Class I well permitting options, as well as a revised cost estimate and project schedule. Overall a deep well injection study is anticipated to cost $25,000 to $40,000 to complete.

Implementation of two duty and one standby deep wells to manage the 0.48 MGD of waste concentrate produced from the proposed facility would result in project costs and savings summarized in Table 6-4.

Table 6-4: Potential Cost Savings from Deep Well Injection

Element	Project With Deep Well Injection	Cost Savings [a]
Total Capital Cost (2014) [b]	$57,200,000	- ($10,200,000)
Annualized Capital Cost (2014)	$3,700,000	- ($700,000)
Annual O&M Cost (2014)	$1,200,000	- ($3,100,000)
Present Worth O&M Costs (2014)	$19,000,000	- ($47,300,000)
Total Annual Costs (2014)	$5,000,000	- ($3,800,000)
Total Present Worth Costs (2014)	$76,200,000	- ($57,500,000)
Unit Cost per AF	$1,651/AF	- ($1,246/AF)
Unit Cost per pound of salt removed	$0.40/lb	- ($0.30/lb)

Notes:
a – Cost Savings = Costs from project using VSEP plus evaporation ponds minus costs from project using deep well injection.
b – Costs include the addition of one supply well to make up for the water not recovered in the concentrate management system

- **Bench Scale Test VSEP System** – This testing will provide more accurate estimates of the maximum feasible membrane flux rates and unit capacities of the VSEP system. If flow rates per membrane stack can exceed 25 gpm, fewer membrane stacks will be required and the capital costs for the infrastructure will decrease.

  Use of VSEP units at 50 gpm per filter pack in combination with evaporation ponds would result in project costs and savings summarized in Table 6-5.

Table 6-5: Potential Cost Savings from Higher Flow VSEP with Evaporation Ponds

Element	Project With High Flow VSEP	Cost Savings [a]
Total Capital Cost (2014)	$55,600,000	- ($11,800,000)
Annualized Capital Cost (2014)	$3,600,000	- ($800,000)
Annual O&M Cost (2014)	$4,100,000	- ($200,000)
Present Worth O&M Costs (2014)	$62,900,000	- ($3,300,000)
Total Annual Costs (2014)	$7,700,000	- ($1,000,000)
Total Present Worth Costs (2014)	$118,500,000	- ($15,100,000)
Unit Cost per AF	$2,570/AF	- ($328/AF)
Unit Cost per pound of salt removed	$0.62/lb	- ($0.08/lb)

Notes:
a – Cost Savings = Costs from project using VSEP plus evaporation ponds minus costs from project using high flow VSEP plus evaporation ponds.

- **Further Study Product Recovery** – Based on the results of the LLNL efforts, there may be a benefit to perform additional product recovery analysis looking into additional treatment processes that may induce precipitation of marketable by-products. For example, GeoProcessors has multiple systems operating in Australia as well as pilot units in the western US to recover marketable salts from the waste concentrate. With a desalination facility removing over 6,000 tons/year of salt from the San Juan Basin, there is the potential to produce products of value to local agriculture or industry. This potential for cost recovery would also decrease the required disposal costs for the waste concentrate as there is additional water recovery and weight reduction through these processes. Due to the sensitivity of this process on the specific water quality and the equipment variations that may be required, no cost estimate was developed for this option.

6.2 Benefit-Cost Analysis

The recommended groundwater desalination project will provide a variety of benefits to the local San Juan Valley/Sub-basin, to the Pajaro River Watershed and to the State of California. Some of the specific beneficiaries from the project include:

- Local M&I Water Customers
- San Juan Sub-Basin Groundwater Users
- US Bureau of Reclamation
- Other CVP Contractors
- Wastewater Dischargers
- Agricultural Land Users
- Public
- Environmental Interests
- Bay-Delta Fish and Wildlife
- Local Rate Payers
- SCVWD
- PVWMA

The following sections outline the benefits and costs of the proposed project. In addition to the financial costs discussed in Section 6.1.5, quantitative and qualitative benefits and costs are taken into account to provide a comprehensive analysis for the proposed project. The project benefits span several categories including water supply and quality, groundwater management and environmental impacts.

6.2.1 Baseline

Currently, municipal and industrial (M&I) water demands in the Hollister area (the Cities of Hollister and San Juan Bautista and unincorporated surrounding areas) are met by a combination of imported CVP water supplies and non-desalinated groundwater. Current and future water demands for the Hollister area are shown in Table 6-6.

Table 6-6: Hollister Area Water Demands

	2005 (actual)	2023 (projected)
Hollister Urban Area Water Demands (AFY)	7,970	11,840
San Juan Bautista Water Demands (AFY)	400	900

Sources: Draft HUAWWMP (December 2006), M. Davis (pers comm., January 2007)

The reliability of existing CVP supplies is anticipated to decrease further over time, significantly reducing M&I entitlement reliability. Without changes to current practices, groundwater quality degradation is expected to continue such that future use of groundwater supplies may be limited. This potential future unreliability of both Hollister area water supplies leaves the area vulnerable to future water shortages due to lack of supply and/or poor source water quality.

6.2.2 Water Supply Options

As discussed in Chapter 1, there are two primary alternatives for providing high quality potable water to the SBCWD service area: importing and treating additional CVP water or desalination of local groundwater.

The proposed groundwater desalination project will produce 2,625 AFY of desalinated groundwater that will be blended with 375 AFY of raw groundwater to provide water users with 3,000 AFY of supply. If the proposed project is not built, additional water supplies will need to be obtained to meet projected future water demands.

The most feasible alternative to the proposed project is to obtain additional CVP M&I water entitlements for importing water supplies. As discussed in Chapter 1, the reliable delivery of CVP M&I entitlements south of the Delta is 85%. With 85% reliability, an additional CVP M&I entitlement of 3,530 AFY would be required to reliably receive 3,000 AFY. Future reliability of CVP water supplies are unknown and could be subject to further reductions due to a number of variables, including Delta water quality and fisheries issues and unknowns associated with global climate change.

6.2.3 Full Range of Benefits and Costs

This section contains a comprehensive list of all expected benefits and costs of the proposed project. Benefits are proceeded with a '+' sign and costs with a '-' sign. Benefits and costs which are small or can be mitigated are discussed in this section but are not analyzed further. Table 6-7 summarizes the benefits described below.

(+) Diversifies Water Supply Sources

The proposed project helps the Pajaro River Watershed water users to diversify their water sources, creating a more reliable, locally controlled water supply when compared to the reliability of additional CVP water deliveries. The reliability of the water supply is especially important to the local area during drought and other source water impacting events.

(+) Provides Local Control of Water Supply

The proposed project allows the SBCWD service area to maintain better local control of their water supplies, making for a more reliable water supply. The proposed groundwater desalination facility provides greater local control and therefore more flexibility in controlling water supply deliveries compared to the minimal control relative to CVP water deliveries.

(+) Improves Potable Water Quality

The proposed project provides a water supply with lower TDS level, well below the California Department of Public Health (CDPH) secondary standard for drinking water of 500 mg/L. The improved quality of the potable water will benefit the water customers. Further, the improved potable water quality leads to improved wastewater quality which will allow the region to implement water recycling which has, to date, been infeasible due to high salinity of the treated wastewater.

(+) Avoids Cost of Acquiring Additional CVP Allocations

The proposed project will postpone the need to acquire any additional CVP supplies for the Hollister Urban Area. The proposed project and the existing CVP supplies are expected to meet projected water demands for the Hollister urban area through the year 2022.

(+) Manages High Groundwater Levels

The proposed project will help to manage high groundwater levels that impact overlying land users in the Hollister Urban Area. Managing high groundwater levels helps to protect not only the urban area but also agricultural lands overlying the aquifer. Agriculture is the largest industry in San Benito County with estimated direct revenue of $268 million[11] in 2005. Management of high groundwater levels protects the agricultural community and the economic viability of the county.

(+) Improves Groundwater Quality

The proposed project permanently removes salt from San Juan Basin groundwater through discharge of the brine from the desalination process. Urban wastewater disposal is one source of salts in the groundwater, and the removal of salts from the wastewater and/or recycled water prior to introduction into the groundwater basin will improve the groundwater quality. Improved groundwater quality will benefit both urban and agricultural users. Additionally the proposed project maintains or improves the current groundwater quality thereby sustaining the usability of groundwater as a water supply for the region.

(+) Caps Salt Imports to Basin

By utilizing the existing local groundwater supply, the need for additional CVP supplies, or other imported water supplies, in the Hollister Urban Area will be delayed until at least the year 2022. This delay will prevent additional salt imports to the basin. By capping salt imports, the groundwater quality improvements can be realized in a timely fashion.

(+) Provides Opportunities for Regional Water Transfers

The proposed project provides additional water supplies and improvements to the local water quality, both of which can be shared and transferred to regional partners. Regional partnerships allow for benefit sharing and potential cost sharing for the overall project. Specifically, transfers of CVP water between regional partners, such as sharing between SCVWD and SBCWD, would help to meet the water supply reliability, diversity and local control needs of these agencies. CVP transfers between SBCWD and SCVWD would be facilitated through a joint service area for CVP water use that encompasses the SBCWD and SCVWD service areas. Further discussion of the potential regional partnerships can be found in Section 6.3, Interagency Cost and Benefit Sharing Opportunities.

(+) Preserves Bay-Delta Habitat

The proposed project helps to preserve the San Francisco Bay-Delta Habitat by utilizing more local water supplies and avoiding importation of additional CVP or similar water supplies. Compared to the overall quantity of CVP supplies, the Pajaro River Watershed's portion is small and the associated magnitude of habitat preservation is uncertain; consequently additional analysis will be required to fully ascertain the magnitude of this benefit.

(-) Reduces Groundwater Flows to the San Benito River and San Juan Creek

The proposed project utilizes more groundwater which will reduce the quantity of groundwater available to recharge the San Benito River and San Juan Creek. With less groundwater recharge, river flows may decline. Initial groundwater basin modeling indicates that the increased pumping in the San Juan Basin would result in a net reduction in river flows equivalent to the pumping rate.

(-) Impacts to Air Quality Near Brine Evaporation Ponds

The proposed project includes uncovered brine evaporation ponds at the treatment facility. The uncovered ponds could potentially have an affect on local area quality due to the high concentrations of salts in the water. Due to the minimal wave energy in the pond and the available mitigation options this impact is not carried forward. This impact would only be incurred for the evaporation pond option and likely only when ponds are dry if the remaining salts are not covered or removed.

---

[11] San Benito County Agricultural Commissioner

(-) Impacts to Waterfowl

The proposed project includes uncovered brine evaporation ponds at the treatment facility. The ponds will contain water with a high concentration of salts which could pose a danger to birds who are attracted to the ponds as a food or habitat source. There are mitigation techniques available to dissuade birds from using the ponds; however, the impact and the proposed mitigation measures will need to be addressed in the environmental analysis of the project. The uncertainly of the acceptance of the mitigation measures provides an additional project risk that may be mitigated through continued investigation of the deep well injection concentrate management alternative.

Table 6-7: Qualitative Summary of Benefits and Costs

Type of Benefit or Cost	Brief Description
Diversifies Water Supply Sources	• Increases water supply reliability
Provides Local Control of Water Supply	• Increases water supply reliability • Allows flexibility in meeting water demands • Reduces dependence on resources governed by other entities
Improves Potable Water Quality	• Protects public health by providing better quality water • Reduces use of home-water softeners • Allows for implementation of water recycling in the local area
Avoids Costs of Acquiring Additional CVP Water Allocations	• Reduces need to import additional water from CVP system in the local area
Manages High Groundwater Levels	• Protects agricultural lands • Preserves main economic resource of the area
Improves Groundwater Quality	• Allows continued use of groundwater in the area • Improves groundwater quality in a sub-basin shared by other agencies
Caps Salt Imports to Sub-Basin	• Eliminates salt loads resulting from additional imported water
Provides Opportunities for Regional Water Transfers	• Provides offset of CVP water for potential transfer to other agencies • Allows for implementation of water recycling, which could be transferred to partners • Provides additional high quality water supply, which could be transferred to partners
Preserves Bay-Delta Habitat	• Reduces water demands from San Joaquin River-San Francisco Bay Delta
Reduces Groundwater Flows to San Benito River	• Reduces amount of groundwater available to recharge San Benito River
Impacts to Air Quality Near Evaporation Ponds	• Results in minor potential for dried salts to be blown from the evaporation pond site
Impacts to Waterfowl	• Provides additional water body for waterfowl habitat • Results in potential uptake of concentrated constituents by birds using the ponds

6.2.4 Benefit-Cost Comparison

For several of the benefits and costs discussed in Section 6.2.3, quantification is feasible to a reasonable level of certainty. For these specific benefits and costs, the estimated annual quantity and the associated unit values are included in Table 6-8. The economic, quantifiable and non-quantifiable benefits and costs of the proposed project are summarized in Table 6-9. Costs are presented in 2014 dollars which is the estimated mid-point of construction of the proposed project.

Table 6-8: Quantification of Non-Economic Benefits and Costs

Benefit Category	Annual Quantity	Unit values and assumptions used	Comments
Avoids Cost of Acquiring Additional CVP Supplies	3,000 AFY of CVP Water Imported to Sub-Basin	$1,450 per AF for South-of-Delta CVP Entitlement purchase (2005$) 60 to 85% reliability of CVP Delivery $155.87 per AFY for USBR Delivery Charges (2005$) $10.72 million for upgrades to Lessalt WTP to treat additional 3000 AFY (2006$) $0.62 million for increased O&M at Lessalt WTP to treat additional 3000 AFY (2006$) $9.87 million for upgrades to CVP piping to transport an additional 3000 AFY (2006$) $0.05 million for increased O&M for additional CVP piping to transport an additional 3000 AFY (2006$)	2005$ and 2006$ converted to 2014$ for consistency.
Caps Basin Salt Imports	3,000 AFY of CVP Water Imported to Sub-Basin	300 mg/L TDS in CVP water $0.70 per lbs of salt removed by desalination (2014$) 80% of salts in CVP water enter GW aquifer	Percentage of CVP water entering GW aquifer is an estimate only.

Sources: Hollister Urban Water and Wastewater master Plan

Table 6-9: Summary of Benefits and Costs

	Annual Dollar Amount (2014$)
Cost Components (includes Capital and O&M)	
Extraction	$648,000
Desalination	$1,116,000
Brine Management	$5,329,000
Distribution	$1,600,000
Total Costs	**$8,693,000**
Benefit Components	
Caps Sub-Basin Salt Imports	$1,370,000
Avoids Costs of Acquiring Additional CVP Water Allocations	$3,710,000 - $3,910,000
Total Monetized Benefits	**$5,080,000 – $5,280,000**
Benefits & Costs requiring Qualitative Assessment [a]	
Diversifies Water Supply Sources	++
Provides Local Control of Water Supply	++
Improves Potable Water Quality	++
Manages High Groundwater Levels	++
Improves Groundwater Quality	++
Preserves Bay-Delta Habitat	+
Opportunities for Regional Water Transfers	
CVP Water	++
Desalinated Groundwater	+
Recycled Water	+
Reduces Groundwater Flows to San Benito River	-

a. Direction and magnitude of effect on net benefits:

++	Very positive impact on net benefits.
+	Positive impact on net benefits.
0	Neutral impact on net benefits.
-	Negative impact on net benefits.
--	Very negative impact on net benefits.

6.3 Interagency Cost and Benefit Sharing Opportunities

As discussed in Section 6.2.3, the proposed project provides many opportunities for regional partnerships. Desalination of San Juan Basin groundwater has been identified in the HUAWWMP as a potential strategy for long-term potable water supply for the greater Hollister area. There is also potential for near-term implementation for regional benefits. A number of available pathways for benefit transfer between regional entities have been identified through the Pajaro River Watershed Integrated Regional Water Management Plan. These pathways are discussed in the following sections.

6.3.1 CVP Water Transfers

SBCWD has a contract for CVP water in the amount of 35,550 AFY for agricultural use and 8,250 AFY for M&I use. The current contract extends to 2027 and may be renewed. Interagency transfers are a potential key project benefit to SBCWD and project partners. While the importation of water from the San Juan Basin (SJB) to the Hollister Urban Area would provide flexibility to SBCWD, and opportunities for M&I CVP water transfers, the implementation schedule determines the quantity and periodicity of available water.

Based on projected supply and demand, there are two options to consider when evaluating the benefits of M&I CVP water transfers between the Project Partners and between SBCWD and other local or regional entities.

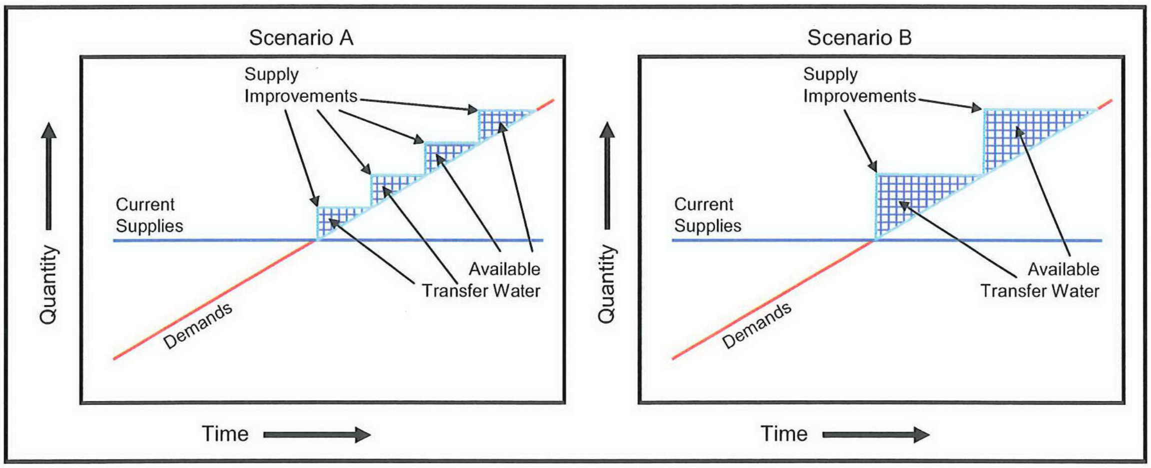
1. periodic transfers in critically dry years
2. near-term annual transfers

The size and schedule of water supply augmentation impact the availability of water for such transfers, as demonstrated in Figure 6-2. There are two main implementation schedule scenarios:

- Scenario A: build smaller capacity water supply enhancement projects as demand increases. This is a short-term approach to water supply capacity improvements.
- Scenario B: build fewer, larger capacity, water supply enhancement projects as demand increases. This is a longer-term approach to water supply capacity improvements.

If project partners time the water supply projects to meet short-term Hollister urban area needs (Figure 6-2, Scenario A), this limits the volume of water available for transfer. If project partners schedule water supply projects to meet longer-term demands, this increases system flexibility and supports additional interagency transfers (Figure 6-2, Scenario B).

Figure 6-2: Water Demand and Supply Expansion Scenarios



SCVWD water resource planning has consistently identified the need to improve water supply reliability, particularly in dry years. Therefore, SCVWD currently has some level of interest in a long-term agreement that provides periodic transfers in critical dry years, but also has some level of interest in near-term transfers. Meanwhile, there are storage options that SCVWD could utilize to store normal and wet year water supplies for use in dry years including groundwater banking and surface reservoir storage. SCVWD is currently connected to the CVP system and has existing facilities that could be utilized to manage additional CVP water that could be transferred from SBCWD.

PVWMA is in need of agricultural water supplies during all years. Contracts with the USBR are currently being renegotiated. The flexibility to use CVP M&I supplies for agricultural uses, and vice versa, is being incorporated into the many of the new contracts. If the new contracts allow for M&I entitlements to be used for agricultural uses, PVWMA could potentially take normal and wet year water. PVWMA does not currently have a connection to the CVP system and would therefore need to add this infrastructure to receive the CVP allocation.

To maintain current water supply priorities in the SBCWD area, and specifically in Zone 6, the only water that would potentially be transferred would be M&I supply. This is due to the needs of SCVWD and the predominant need for agricultural CVP water in the SBCWD area.

Periodic Transfers in Critically Dry Years

In this scenario, SBCWD would implement the water supply infrastructure needed for Hollister urban area consistent with the proposed implementation schedule contained in the Hollister Urban Area Water and Wastewater Plan (HUAWWMP). Through optimum use of available CVP water in normal and wet years, SBCWD would effectively bank water in the local groundwater basins by offsetting additional groundwater pumping. This is local banking operation cold provide an opportunity in critically dry years to transfer CVP allocations to another agency while temporarily pumping additional groundwater, effectively reducing the banked groundwater. Figure 6-3 shows how this might work for a year with a total M&I demand of 11,800 AFY (roughly corresponding to projected demands in 2023). If this was a normal-to-wet year, the majority of the supply would be from CVP water (left bar) while if it was a dry year, the majority of the supply would be from groundwater (right bar). The difference in the quantity of CVP water used would potentially be available for transfer, subject to any supply restrictions imposed by the USBR for the CVP system. The remainder of the potable water required for that year could be supplied from the groundwater basin which had been allowed to fill up during normal and wet years when the CVP water supply reliability is higher than that during dry years.

Figure 6-3: Conceptual Wet Year/Dry-Year M&I Supply Scenario for the Hollister Urban Area

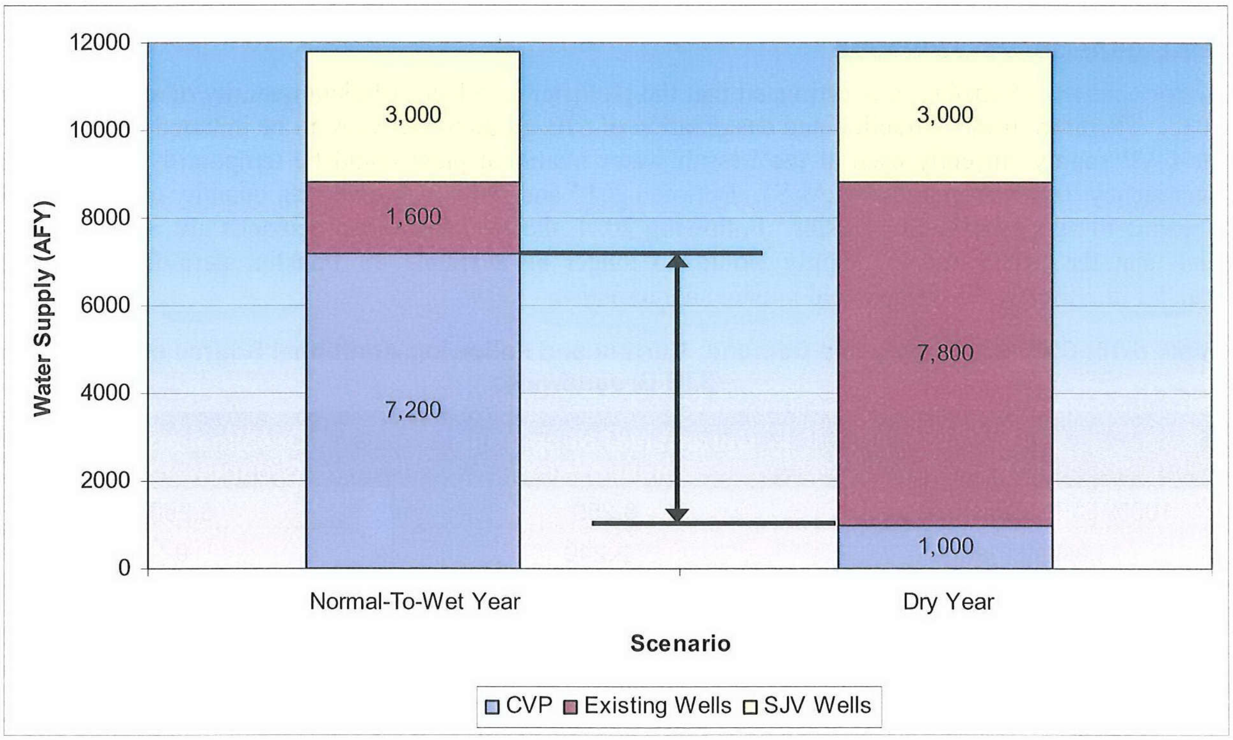
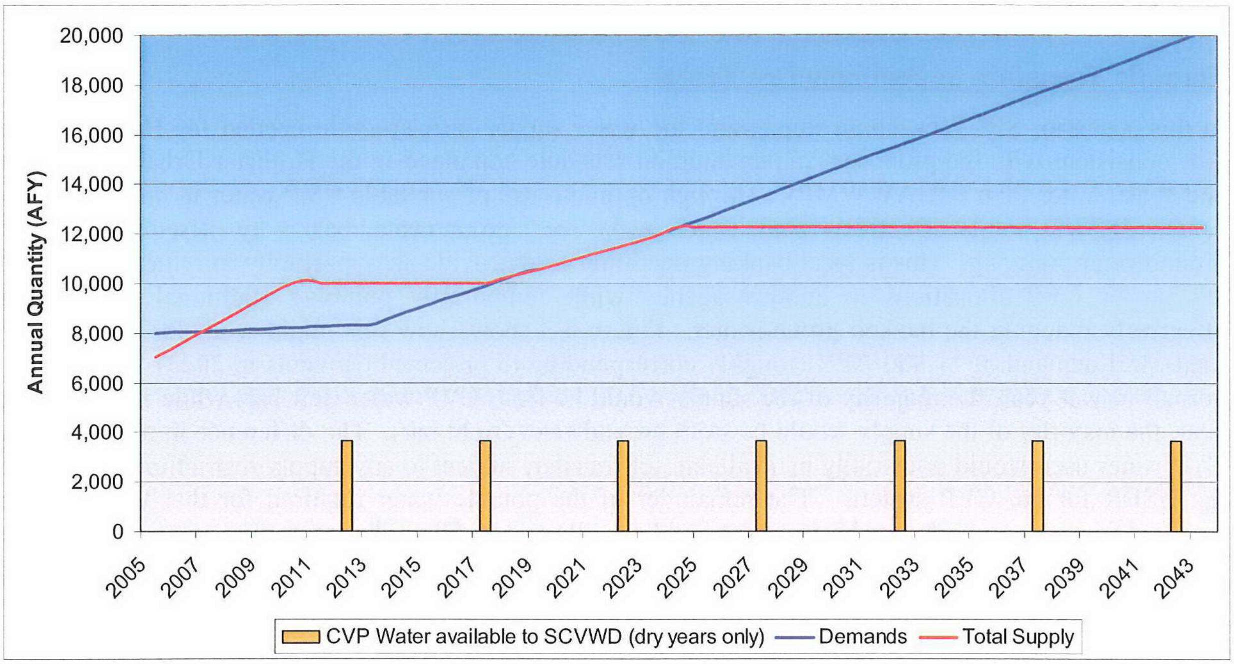


Figure 6-4 shows one potential schedule of dry year transfers from SBCWD to a regional partner. This schedule assumes that dry years occur one out of every five years and CVP water availability is at the USBR minimum, 50% of contracted maximum. This would result in approximately 3,600 AFY of water available for transfer every five years.

Figure 6-4: Potential Dry Year Transfer Schedule



Near Term Annual Transfers

As for near-term transfers, it is estimated that the Hollister area has sufficient quantity of supply through 2015. Therefore if the extraction and desalination of SJB groundwater were to be initiated prior to 2015, the CVP supply currently used at the Lessalt water treatment plant could be temporarily available for interagency transfer (up to 2,240 AFY). Between 2015 and 2024, a diminishing quantity of water would continue to be available for transfer. Following 2024, the Hollister urban demands are projected to be such that the SBCWD CVP supply would no longer be available for transfer; periodic interagency transfer in critically dry years could remain an alternative.

Table 6-10: CVP M&I Supply and Demand: Current and Following Additional Source of Desalinated SJB Groundwater

	Current M&I Supply and Demand (AFY)	Desalination of SJB Groundwater (AFY)
100% CVP M&I Contract	8,250	8,250
Lessalt Plant	- 2,240	0
Other M&I uses	- 1,000	- 1,000
Remaining Available Water	5,010	7,250

Note: Actual amount of available water will be a function of Bureau of Reclamation CVP supply restrictions in place for any given year.

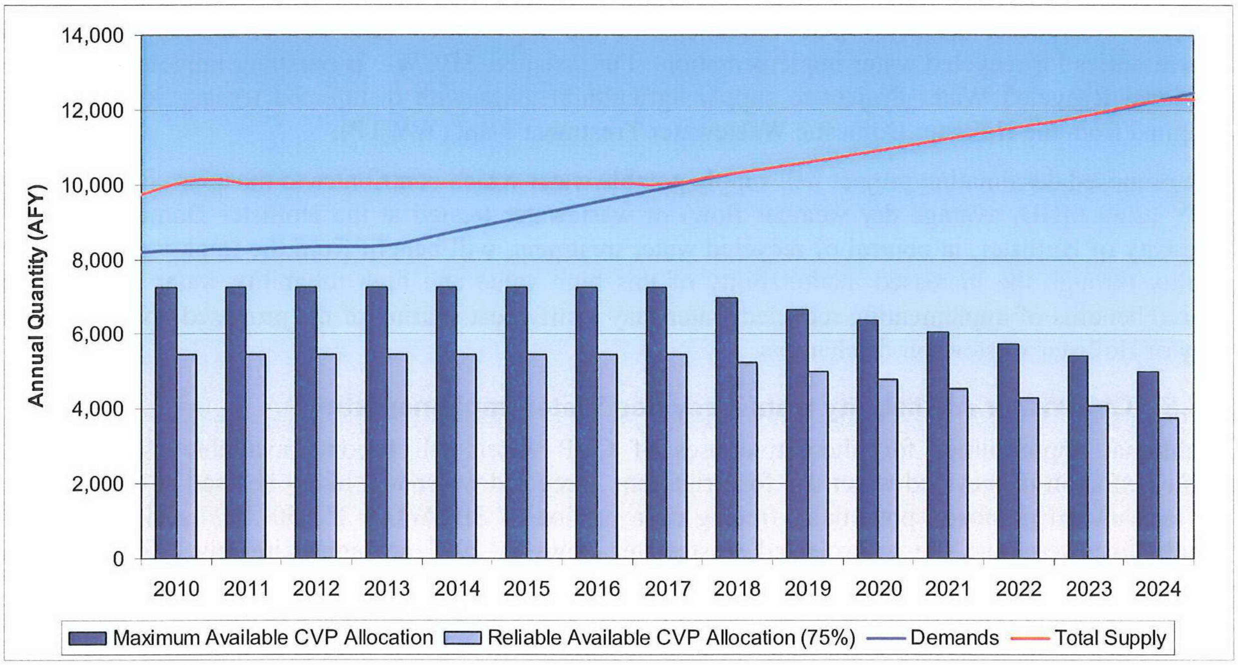
As presented in Table 6-10, up to 7,250 AFY of CVP M&I supply could become available annually through 2015. After 2015, the projected water demands begin exceeding water supply for the Hollister urban area. At that point, per recommendations in the HUAWWMP, the urban area would initiate desalination of SJB groundwater to meet M&I demands.

A 3,000 AFY desalination facility for SJB groundwater is projected to be required to meet the urban demands through 2024. Therefore if such a facility were operational by 2015, there would be some excess capacity available in the years spanning 2015 and 2024, diminishing as the Hollister urban area demands increase, at which point the SBCWD would need additional reliable water supplies for the region, including their CVP allocation and the full capacity of the Lessalt facility. The potential availability of CVP supply could be increased if implementation of the proposed desalination facility for SJB groundwater were accelerated and the facility were to become operational by 2010.

Following 2024, the Hollister urban demands are projected to be such that additional supplies will be needed beyond the 3,000 AFY. At that time, the SBCWD CVP allocations would no longer available for transfer. The periodic interagency transfer in critically dry years would remain an alternative, per the discussion in the preceding section.

Figure 6-5 shows potential CVP water transfers for the 100% supply scenario and the 75% supply scenario, corresponding to 75th percentile water availability, for wet years. Under these conditions a total of 75,000 to 100,000 AF of wet year water supplies could be transferred to SCVWD over 15 years between the earliest potential completion date for a desalination facility (2010) and the time when the water demand in the Hollister Urban Area exceeds the supply for the area (2024).

Figure 6-5: Potential Near-Term Wet-Year Water Transfer Schedule



6.3.2 Desalinated Groundwater Transfers

The proposed project provides the opportunity to transfer up to 2,625 AFY of non-blended desalinated groundwater to others. SBCWD will need to determine how much of the desalinated groundwater supply they are willing to transfer, specifically under what circumstances (e.g. wet years only) and as water demand increases in the future.

SCVWD has a potential need for dry year M&I supplies. Depending upon SBCWD's determination, SCVWD could develop an agreement to receive desalinated groundwater during dry years. To do so would require an intertie between the treated groundwater system and the SCVWD system.

PVWMA is in need of agricultural water supplies in all years. The quality of the water produced by the proposed project is expected to greatly exceed the quality of water required for agricultural irrigation. The desalinated groundwater could be blended with other PVWMA supplies to provide product water that meets the needs of the agricultural customers. PVWMA would need to develop an intertie with the SBCWD water distribution infrastructure to make this transfer possible. Due to the lack of connection and the high costs for water treatment and conveyance, it is unlikely that this interagency collaboration would be a viable option.

6.3.3 Groundwater Quality Improvements

As discussed in Section 6.2.3, the proposed project will improve groundwater quality in the San Juan Sub-basin. SBCWD is only one of the users of this groundwater sub-basin and there are several others who will benefit from improvements in the groundwater quality. Many private agricultural wells, private potable wells and a small number of municipal wells utilize groundwater supplies from this groundwater basin including the City of San Juan Bautista. The shared benefits of improvements to groundwater quality may justify cost-sharing of the proposed project with the City of San Juan Bautista.

Additionally, the local groundwater basins provide recharge to the Pajaro River and its tributaries. Improvements in the local groundwater quality would improve the quality of the water recharged to the Pajaro River and would provide this higher quality water to downstream beneficial uses.

6.3.4 Recycled Water Implementation Opportunities

As discussed in Section 6.2.3, the proposed project will improve potable water quality which will in turn improve wastewater quality. The reductions in the wastewater TDS concentrations will provide opportunities for recycled water implementation. For instance, SBCWD is pursuing implementation of a Regional Recycled Water Project to supply agricultural users with disinfected tertiary recycled water supplied from the Hollister Domestic Wastewater Treatment Plant (WWTP).

The proposed desalination project will supply potable water which contributes to the approximately 3,000 AFY (2.69 MGD, average dry weather flow) of wastewater treated at the Hollister Domestic WWTP. The City of Hollister, in control of recycled water treatment, will benefit from the improved wastewater quality through the increased marketability of this high value and high reliability water supply. The shared benefits of implementing recycled water may justify cost-sharing of the proposed project with the City of Hollister wastewater dischargers.

6.3.5 CVP Water Availability from Recycled Water Implementation

Additional opportunities for alternative uses of CVP water will become available as a result of implementation of recycled water use for irrigation. Recycled water will likely be used in the local area for agricultural purposes, potentially freeing up a portion of SBCWD's 35,550 AFY agricultural CVP supply for alternative uses. Projected wastewater flows in 2015 are approximately 3,660 AFY and assuming that approximately 2/3 of these flows are available for off-site recycled water use, 2,450 AFY of recycled water could be distributed. This quantity would increase annually as growth in the Hollister Urban Area generates more wastewater that can be treated for recycled water applications. The 2,450 AFY of recycled water to increase the total amount of agricultural water supply within San Benito County or to offset existing CVP agricultural water.

In addition to potential increased delivery of agricultural irrigation supplies within San Benito County, both SCVWD and PVWMA have uses for agricultural water supplies. PVWMA does not currently have a connection to the CVP system and would therefore need to add this infrastructure to receive the CVP allocation.

6.3.6 Required Interagency Agreements

A number of agreements will need to be developed for the various potential partnerships identified in preceding sections. Depending upon which sharing opportunities may be pursued, agreements for cost-benefit sharing will be needed between the interested parties.

The Pajaro River Watershed Integrated Regional Water Management (IRWM) Planning efforts provide the supporting framework for developing additional agreements between partners. As discussed in Chapter 1, the groundwater desalination project has been identified as an integral part of the overall

IRWM Plan and should therefore have the support of the regional partners and various stakeholders. The results of the IRWM planning efforts will be to further investigate and develop the recommended projects, including aiding in determining the most acceptable course of action for sharing the costs and benefits of the proposed project. The San Juan Valley desalination project was also identified in the Hollister Urban Area Water and Wastewater Master Plan as a recommended project for implementation.

The following is a brief summary of some of the possible agreements that may be required depending on the form of joint projects that may be pursued.

San Benito County and Santa Clara Valley Water Districts

- Potential transfers of CVP M&I allocations during normal, wet and dry years
- Potential transfers of desalinated groundwater

San Benito County Water District and Pajaro Valley Water Management Agency

- Potential transfers of CVP M&I allocations during normal, wet and dry years
- Potential transfers of CVP agricultural allocations during normal, wet and dry years

San Benito County Water District and City of San Juan Bautista

- Potential cost sharing for improved groundwater quality

San Benito County Water District and City of Hollister

- Potential cost sharing for recycled water implementation due to improved potable water quality

6.4 Implementation Strategy

There are several project elements that must be addressed and completed during the actual implementation of the recommended desalination facility. These elements include financial planning, environmental permitting and regulatory acceptance components.

6.4.1 Financing Strategy

For a project with projected capital costs ranging from $57 million to $67 million, the methods of project financing can be critical to the ultimate success of the implementation. There are four main options for project financing:

- Grants
- Loans
- Rate-secured bonds
- Federal financial assistance

Grants

In recent years, state grant funding for water projects has been primarily backed by Proposition 50 through one or more of its several chapters. One of the major funding processes through Proposition 50 was the Integrated Regional Water Management (IRWM) program. This program granted $380 million to California regions to plan and implement regional solutions for water supply, wastewater treatment, flood protection and environmental enhancement. All of the money allocated through this measure for water supply projects has been allocated.

Additional water supply funding is anticipated to be available through Proposition 84, passed in November 2006. Proposition 84 includes $1 billion in funding for integrated regional water management as well as $525 million for safe drinking water and water quality projects. The San Juan Basin

Groundwater Desalination Project could potentially be funded through either of these two funding sources and a determination of which grant sources to apply for will need to be made after grant requirements are developed and distributed.

Loans

The Drinking Water State Revolving Fund (DWSRF) is a federal loan program administered in California by CDPH. This program provides low interest loans for public water system infrastructure needs and other drinking water-related activities, however the funds can\not be used for projects primarily used to supply future growth. The need to reduce the TDS concentration to meet the secondary standard for TDS concentrations in potable water would qualify this project for funding under this loan program and depending on the timing of the application, there is a potential that the project could be deemed to be for more than just future growth requirements. This program typically accepts applications for inclusion on its priority list once each year and then funds projects as money becomes available.

Rate-Secured Bonds

The implementing agency could sell bonds to finance the project costs over a long period of time, typically 20 to 30 years. These bonds would be repaid through an increase in water rates, assessments, or other revenues that would be used to pay the interest and principal on the bonds.

Federal Financial Assistance

There are several other potential options for financial assistance through the federal government. These options include general funding sources and specific earmarks in federal funding legislation. One potential source of federal funding is the Water Resources Development Act (WRDA), which is intended to be reauthorized every two years, but has not been regular in its timing in the last several years.

6.4.2 Major Environmental Considerations & Constraints

Another critical step that will need to be taken during the detailed planning and design stage is the preparation of environmental documentation to satisfy the California Environmental Quality Act (CEQA) and, if a federal nexus exists, the National Environmental Policy Act (NEPA). These documents will identify the environmental impacts from the project and the mitigation measures that will be taken to reduce these impacts to a less-than-significant level. Some of the currently identified environmental considerations and constraints that will need to be addressed in that document are:

- Impacts of increased groundwater extraction in the San Juan Valley – This element is preliminarily addressed in Chapter 2: Source Water Evaluation through the modeling work performed for the identified extraction alternatives. Additional modeling may be required to address more specific details of the groundwater extraction operation including the synergistic impacts of the desalination extractions in conjunction with implementation of a recycled water project in the same general area.
- Impacts of the construction of raw groundwater piping from the well locations to the treatment facility
- Impacts of the construction of the treatment facility – Various treatment facility sites may need to be considered to address potential environmental constraints
- Impacts of RO membrane process including energy demand and cleaning chemical disposal
- Impacts of waste concentrate management – Any of the potential concentrate management options (evaporation ponds, VSEP or deep well injection) will have specific impacts or considerations that need to be addressed. Some of these potential considerations are land purchases and its impact on agricultural practices, air quality and waterfowl habitat impacts from evaporation ponds, construction of concentrate conveyance piping, energy use of the

VSEP process, visual impacts of the facilities, VSEP cleaning chemical disposal, construction impacts of multiple deep wells and operating impacts of the injection wells.

- Impacts of the construction of product water piping from treatment facility to the recipient potable water system
- Evaluation of overall project impacts on potential cultural or archeological resources

Expansion of water supply facilities are typically associated with growth-inducing impacts, however it is assumed that these impacts will be addressed in the environmental documentation associated with the Hollister Urban Area Water and Wastewater Master Plan, which may include documentation for a San Juan Valley groundwater desalination project. A portion of the documentation has previously been provided in the Programmatic Environmental Impact Report prepared in conjunction with the Groundwater Management Plan Update document.

6.4.3 Required Implementation Permits

Implementation of a groundwater desalination project will require several permits to be acquired prior to construction and operations. These permits will allow the construction to proceed and will allow the facility to operate and deliver potable water to customers in the region. Table 6-11 summarizes a preliminary list of the required permits. This list is not exhaustive and some listed permits may not be required for this specific project. A more detailed assessment will be undertaken during the preliminary design stage.

Table 6-11: Preliminary List of Project Permitting Needs

Permit	Governing Agency
Water Supply Permit	Department of Public Health
Waste Discharge Requirements	Central Coast Regional Water Quality Control Board
Stream Bed Alteration Permit	California Department of Fish and Game
Excavation Permit	California Department of Industrial Safety
Encroachment Permit	San Benito County City of Hollister CalTrans
Air Quality Permit	Monterey Bay Unified Air Pollution Control District
Well Construction Permit	San Benito County Water District County of San Benito Public Health Department
Storm Water Pollution Prevention Plan	State Water Resources Control Board
Deep Well Injection Permit	United States Environmental Protection Agency

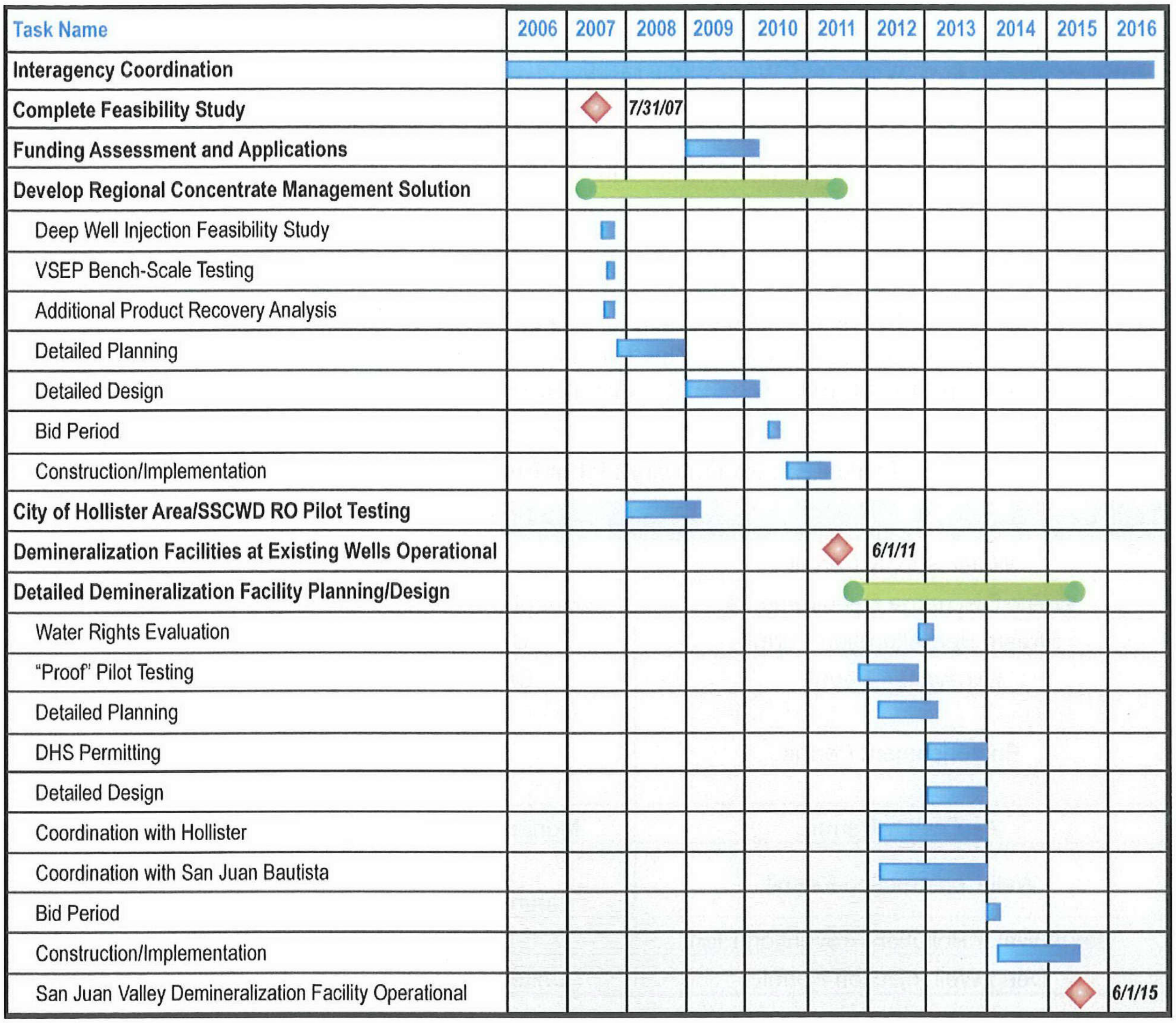
6.4.4 Public Outreach Strategy

Public outreach during the implementation process will be critical to the overall success of the project. As part of the Hollister Urban Area Water and Wastewater Master Plan, the outreach for this project will be coordinated with, and be integral to, the overall outreach occurring as part of the Master Plan implementation. Additionally, through the environmental documentation process, it is anticipated that stakeholders and the public will have the opportunity to review the project and provide their comments through face-to-face and written forums.

6.4.5 Implementation Schedule

Based on recommendations from the Hollister Urban Area Water and Wastewater Master Plan, desalination of groundwater from the San Juan Valley would be implemented to begin serving high quality potable water by 2015. Other desalination elements are identified for implementation beginning in 2011. This earlier implementation date may necessitate the development of a regional concentrate management solution at this time, instead of in conjunction with the San Juan Valley desalination project. Figure 6-6 identifies many of the major implementation tasks for the development of desalination for San Juan Valley groundwater and a regional waste concentrate management solution.

Figure 6-6: Proposed Implementation Schedule



6.5 Coordination with Study Objectives & Goals

The goals and objectives of the Pajaro River Watershed Groundwater Desalination Feasibility Study are identified in Chapter 1. These goals, and the corresponding results from the Study, are discussed below.

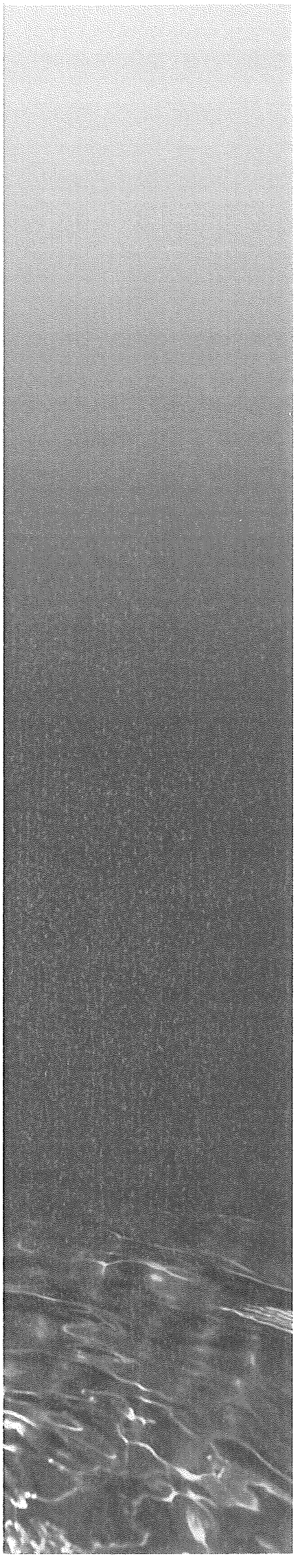
1. *Evaluate the feasibility and cost-effectiveness of treating brackish groundwater for potable use: Is a sufficient quantity of information assembled to make a determination of the technical feasibility, economic viability and public acceptance of the desalination project?*
    - Based on the reverse osmosis pilot study and the additional technical information developed during the Study, desalination of brackish groundwater is a technically feasible option for potable water treatment in the Pajaro River Watershed.

- The cost-benefit assessment identified substantial monetary and non-monetary benefits resulting from the desalination project that are anticipated to show a benefit-cost ratio greater than one.

2. *Assess different treatment technologies and brine management methods to provide the highest level of benefits to the Pajaro River Watershed: Were the best available technologies for brackish groundwater desalination and waste brine management assessed using objective criteria for the specific considerations present in the San Juan Valley?*
    - All of the currently available major desalination technologies (reverse osmosis, nanofiltration, electrodialysis reversal and thermal processes) were assessed using technical, economic and public acceptance criteria to determine the most suitable process for the Pajaro River Watershed as a whole and specifically the San Juan Valley.
    - Traditional and innovative brine management technologies were identified and assessed using objective criteria to establish a current recommendation for brine management as well as areas for additional investigation for the region. Potential cost savings options were also identified for the recommended facilities.
3. *Quantify the offset of CVP water use due to the use of local groundwater as a new, alternative potable water source: What quantity of potable water can be expected to be beneficially used to offset current or projected future CVP water use in San Benito County and what impacts will this have on water reclamation and groundwater sustainability?*
    - Each unit of desalinated groundwater will offset the potential use of one unit of additional imported CVP water in the future. Using the San Juan Valley as a source can reliably and sustainably provide 3,000 acre-feet per year of a new, high quality, reliable potable water supply for San Benito County.
    - The use of this high quality potable water will improve the potential for water reclamation as the dissolved salt loading into the wastewater system would be reduced both from the reduction in salts in the potable water and the decreased need for in-home water softeners.
    - The removal of salts from the groundwater basin through final disposal of the waste brine will, over time, increase the overall quality of the groundwater and result in a higher value resource.
4. *Identify benefits and mechanisms to transfer and assure equitable benefits throughout the Pajaro River Watershed as well as the State and the Bay-Delta system: Does the project provide significant benefits to the Project Partners? Can local benefits from the groundwater desalination project create benefits for other watershed partners as well as the State and the Bay-Delta water supply system and are these benefits sufficient to provide continued interest in the project from the beneficiaries?*
    - The monetary project benefits include capping salt imports to the Sub-Basin and reducing the need for additional CVP deliveries. These benefits have been estimated to offset about 60% of the estimated project costs (Table 6-9). The Project Partners (SBCWD, SCVWD and DWR) are significant beneficiaries of the project while other local entities may realize additional benefits from the implementation of groundwater desalination from the San Juan Valley.
    - The non-monetary benefits are significant and, at this feasibility level of study, result in an overall benefit-cost ratio greater than one.
    - The local benefits of an additional water supply with increased reliability and local control allow for the potential reduction in use of CVP water. A reduction in use would allow for more water available to the Bay-Delta habitat or could potentially allow for wet-to-normal and dry year CVP water transfers to regional water suppliers, such as

SCVWD. The prospect of additional high quality dry year water supply provides an opportunity to help meet an identified long-term objective for SCVWD and other regional water agencies and is anticipated to maintain regional interest in the project.

5. *Provide the basis for future demonstration and full-scale project implementation projects in the San Juan Sub-Basin to yield roughly 3,000 acre-feet per year of new water supply: Will the recommended project be ready to move into subsequent phases that will continue to move towards implementation of a new water supply for the Pajaro River Watershed?*
    - The recommended project identifies a combination of facilities that will enable the next implementation step to be taken toward developing a new supply for the Pajaro River Watershed. The next identified step is to further evaluate the alternative brine management strategies that have the potential to reduce costs and provide additional benefits for the project partners and water users. Other specific next steps include well site identification and "proof" pilot testing of specific reverse osmosis membranes on water drawn from an identified well site.
    - The San Juan Valley groundwater desalination facility was also identified in the Hollister Urban Water and Wastewater Master Plan as a recommended facility and implementation of this project is planned to be in conjunction with the implementation of the other recommended elements of the Master Plan.



References

Pajaro River Watershed Groundwater Desalination Feasibility Study

References

Arakel, A. (2005). Desalination Effluent Management – From Evolutionary Approaches to Revolutionary Zero Liquid Discharge Targets. AWWA 2005 Annual Conference. San Francisco, CA.

Barker, M., 2003. "Desalination in the United States." Frost & Sullivan Market Insight, 28 July 2003

Bureau of Reclamation. Report No. 29. Water Treatment Engineering and Research Group, Technical Service Center, U.S. Department of The Interior. Pp 4.4-4.6.Buros, O.K. 2000. "The ABC's of Desalting. Second Edition." International Desalination Association, Massachusetts, USA. February 2000

Central Coast Regional Water Quality Control Board. 2003. Waste Discharge Requirements Order No. R3-2003-0040/NPDES Permit No. CA0048216 for the City of Watsonville Wastewater Treatment Facility, Santa Cruz County

Chang, Yu-Jung, September/October 2006. Personal Communications.

Griffin, S. J., Schooley, K. E., Solomon, R. L. (2004). The Advantage of Mixed Salt Crystallizers in Zero Liquid Discharge Wastewater Treatment Systems. Retrieved May 26, 2006 from www.ionics.com

HDR, Inc. December 2006. Preliminary Draft *Hollister Urban Water and Wastewater Master Plan.* Prepared for City of Hollister, San Benito County Water District and San Benito County, Hollister, CA.

Heins, W. (2004). Zero Liquid Discharge Wastewater Recycling at Apache Nitrogen Products. Retrieved May 26, 2006 from www.ionics.com

Kennedy/Jenks Consultants. Groundwater Management Plan Update for the San Benito County Part of the Gilroy-Hollister Groundwater Basin. April 2004.

Mesa, A.A., et al., 1996, Energy Saving and Desalination of Water, *Desalination*, 108 (1996): 43-50.

Mickley, M.C. Membrane Concentrate Disposal: Practices and Regulation, 2nd ed.; prepared by Mickley & Associates for the U.S. Dept. of Interior, Bureau of Reclamation. 2004.

Montgomery Watson. September 2000. *Phase 1 Facility Plan.* Prepared for City of San Juan Bautista, San Juan Bautista, CA.

Mulhern, N (1995). "Death, Taxes and RO Membrane Fouling". *Water Technology.* November 1995.

NDWC. 1999. "Tech Brief - Membrane Filtration." A National Drinking Water Clearinghouse Fact Sheet, National Drinking Water Clearinghouse. Ten March, 1999.

Pantell, S.E. et al. 1993. "Seawater Desalination in California: Chapter 1 – Background." California Coastal Commission. October 1993

Raucher, Robert. An Economic Framework for Evaluating the Benefits and Costs of Water Reuse. Final Project Report and User Guidance. WateReuse Foundation. 2006.

Reahl, Eugene R. (2004), "Half a Century of Desalination with Electrodialysis". Ionics Technical Paper #500.

RMC Water and Environment. May 2005. *San Benito County Regional Recycled Water Project Final Feasibility Study Report.* Prepared for Water Resources Association of San Benito County and San Benito County Water District, Hollister, CA.

Santa Barbara County Department of Public Works Staff. July – October 2006. Personal Communications.

San Benito County Water District. Draft Program Environmental Impact Report for the Groundwater Management Plan Update for the San Benito County Portion of the Gilroy-Hollister Groundwater Basin

San Benito County Website. < http://www.san-benito.ca.us/departments/ag/crop_report.htm> Visited 23 February 2007.

Todd Engineers. June 2004. Development of a water quality monitoring program for the Hollister groundwater basin. Final. Emeryville, CA. Prepared for San Benito County Water District, Hollister, CA.

UCLA Engineering (2004), "UCLA Engineering History, 1965-1974". Henri Sameuli School of Engineering and Applied Science. http://www.engineer.ucla.edu/history/osmosis.html (viewed on December 4, 2005).

UNEP – International Environmental Technology Centre. 1997. "Source Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean." United Nations Environment Programme. Chapter 2.2

USEPA. 1990. Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

von Gottenberg, Antonia J.M. and Janet M. Persechino (2000), "Using Membrane Filtration as Pretreatment for Reverse Osmosis to Improve System Performance". *North American Biennial Conference of the American Desalting Association.* August 7, 2000.

Weimer, L. September 2006. Personal Communications.

Wilbert, M.C. et. al. 1998. "The Desalting and Water Treatment Membrane Manual: A Guide To Membranes For Municipal Water Treatment (2nd Edition)." Water Treatment Technology Program U.S.

Yates, Gus. December 19, 2005. Annual groundwater report for water year 2005. Final. Berkeley, CA. Prepared for San Benito County Water District, Hollister, CA.